Assessment and Validation of the Fire Brigade Intervention Model for use within New Zealand and Performance-Based Fire Engineering

by

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Rescuing Mr K. Ballantyne from the burning building on Colombo Street, Christchurch

The worst fire in New Zealand's history occurred on the 18th November 1947 at Ballantynes department store in Christchurch. The fire was first observed by a staff member at 3.35 p.m at which time an estimated 250–300 people were shopping at the store, served by a reported staff of 458. In total, 41 people perished in the fire, and these deaths have been attributed to the delay in placing the call to the fire brigade and possibly the brigade's purported delayed response which occurred at 3.48 p.m[1]. At its height, there were 19 appliances in attendance, crewed by 230 fire fighters and armed service personnel[2]. The Royal Commission of Inquiry that followed resulted in the 1949 Fire Services Act which was the first attempt at standardisation of the Fire Service.

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[1] New Zealand History Online
[2] The New Zealand Fire Service Magazine, Issue 36. December 2007

ABSTRACT

The Fire Brigade Intervention Model (FBIM) has been in use for over a decade and is used regularly throughout Australia and to a lesser extent in New Zealand. Since November 2008, the FBIM has been referenced within the New Zealand compliance document C/AS1 and is accepted by the New Zealand Fire Service (NZFS) as a suitable methodology to demonstrate the performance requirements of the New Zealand Building Code (NZBC) relating to fire brigade operations. However, the FBIM currently has no New Zealand data available to reflect NZFS operations. At present, building designs are using Australian data which is potentially dated and which has only undergone limited validation for New Zealand conditions.

An analysis of building consent applications as submitted to the NZFS for review has been undertaken with specific emphasis on quantifying the impact of alternative fire engineering designs and fire-fighting facilities. This statistical review has indicated that up to 67% of all the fire reports reviewed contained insufficient information to demonstrate compliance with the requirements of the NZBC. For new buildings that contained alternative fire engineering designs, the NZFS made recommendations specific to fire-fighting facilities in 63% of the reports reviewed.

A review of international performance-based building codes is provided to compare international performance requirements and expectations on responding fire fighters from overseas codes. The NZBC and prescriptive requirements are also discussed for their requirements and implications for fire-fighting requirements.

This project presents data that has been collected from a number of sources including specifically designed exercises, NZFS incident statistics, incident video footage and from attendance and observation at emergency incidents. Validation of this data has been undertaken against fire ground field experiments and with real emergency incidents attended during this research.

A FBIM is provided based on the data presented in this research using a probabilistic risk-based approach and Monte-Carlo analysis methods considering a high-rise building scenario. This identifies some of the advantages of using probabilistic methods and the FBIM rather than the traditional percentile approach. An FBIM analysis allows the building designer to factor in the effects of fire fighters on the building design and to identify areas of the building design that may need further consideration.

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NOMENCLATURE

Abbreviations

ABCB	Australian Building Codes Board
AFAC	Australasian Fire and Emergency Services Authorities Council
BCA	Building Code of Australia
BIA	Building Industry Authority
BIC	British Instantaneous Couplings
CAD	Computer Aided Dispatch
CBD	Central Business District
CFA	Country Fire Authority
DBH	Department of Building and Housing
DRU	Design Review Unit
EP&A	Environmental Planning and Assessment Regulation 2000
ETA	Event Tree Analysis
FAP	Fire Alarm Panel
FBIM	Fire Brigade Intervention Model
FEB	Fire Engineering Brief
FIRS	Fire Incident Reporting System
FiRECAM	Fire Risk Evaluation and Cost Assessment Model
FIERAsystem	Fire Evaluation and Risk Assessment system
FDEM	Fire Department Effectiveness Model
FDRM	Fire Department Response Model
ICAD	Intergraph Computer Aided Dispatch System
ICC	International Code Council

ICCPC	International Code Council Performance Code
IFEG	International Fire Engineering Guidelines
MFB	Melbourne Metropolitan Fire Service
MFESB	Metropolitan Fire and Emergency Services Board
MFS	South Australian Metropolitan Fire Service
NRC	National Research Council of Canada
NRFA	National Rural Fire Authority
NSW	New South Wales
NSWFB	New South Wales Fire Service
NZBC	New Zealand Building Code
NZFS	New Zealand Fire Service
NZFSC	New Zealand Fire Service Commission
OIC	Officer in Charge
PFA	Private Fire Alarms
PPE	Personal Protective Equipment or Structural Fire Fighting Clothing
QFRS	Queensland Fire and Rescue Service
QRA	Quantitative Risk Analysis
RFD	Rural Fire District
SACFS	South Australian Country Fire Service
SOP	Standard Operational Procedures
UFD	Urban Fire District

TABLE OF CONTENTS

Appendices

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

1.1. Impetus for Research

Fire engineering is a relatively new engineering discipline requiring knowledge of complex fire phenomenon to understand its impact on occupants of a building, the surrounding environment and the wider community. To enable performance-based fire engineering design to be undertaken appropriately, the gaps that exist in the knowledge of fire science and engineering must be filled so that designs can be approached from a holistic basis. Currently there are many assumptions made in fire engineering designs which lack the understanding of their impact on the outcome of a fire event, be it financial, environmental or through injuries and illness caused to building occupants or emergency responders. In fire engineering there is no bigger void that requires filling than that regarding the intervention of the emergency services and specifically the impact of responding fire brigades on building designs.

One of the most significant changes made to fire safety regulation in New Zealand was the inclusion of the NZFS as a reviewer of alternative building designs required by the Building Act 2004 (the Act). The 2004 Act requires that certain building consent applications be provided to the NZFSC for review and to provide advice to Building Consent Authorities with respect to means of egress and fire-fighting needs.

The NZFS Design Review Unit (DRU) began reviewing building consent applications on the 22nd April 2005. Before this time, information regarding the design of fire-fighting facilities within buildings was unknown to the NZFS and due to the nature of building consent processing, unquantifiable. However, the NZFS was aware through building inspections and emergency incidents that buildings were being designed and built that did not meet NZFS expectations and fire-fighters' needs. Since 2005, the NZFS have identified that building designs submitted for Building Consent frequently ignore the requirements and needs of the NZFS within alternative designs. Further, when dealing with designs that deviate significantly from the prescriptive requirements of the NZBC compliance documents, some designs that were reviewed were acknowledged by the designer to have completely ignored fire-fighting intervention aspects and the impact of the NZFS on the design.

Whilst there is qualitative evidence to suggest that buildings are becoming more difficult for fire fighters to operate within, the potential exists for larger and more complex modern buildings to be more dangerous than historic and prescriptive codes and designs envisaged.

The author believes that because of the lack of analysis and assessment regarding fire fighting intervention within building designs, this could become a serious problem if the current trend to ignore fire-fighting facilities identified within this report continues. A number of designs have been submitted to the NZFS for review which, in this authors opinion, could place occupants and fire fighters at an increased level of risk due to the methods of design chosen and because the designers ignored the implications of the design on fire fighters entering the building. This perception has also been a finding of other overseas brigades involved in the assessment of performance-based fire engineering designs (1).

The increased use of performance-based design, speed of development of new assessment methods and the modern building construction methods, techniques and materials in use is outpacing the understanding of the consequences on fire fighting. The requirements presently in place within prescriptive compliance documents and standards for fire-fighting equipment and their design intent have typically been based on knowledge of historic building performance in fire; therefore, the relevance and adequacy of these requirements when used for performance-based designs needs to be questioned. Additionally the use of modern materials, construction methods and designs may also have an impact on the assumptions that went into the formulation of the historic prescriptive methods (2).

Many fire-fighting operational procedures and the requirements they place on building designs are prescriptive in nature which is problematic for those striving for pure performance-based design. However, by quantifying the tenability parameters to which fire fighters can be subjected to and by setting accepted performance criteria for fire brigade operations, the assessment of fire brigade intervention can be undertaken just as it can be for occupants escaping from a building.

Fire fighters have limitations on their ability to fight fires and operate within buildings as shown by UK research (3; 4). Building designs requiring fire fighters to enter deeper into fire compartments for prolonged periods and with increased difficulty in reaching the fire floor, as with tall buildings, may place fire fighters at greater levels of risk than if the buildings were to comply with prescriptive regulations. Without assessing the impact that designs will have on the ability for fire fighters to undertake search and rescue and fire fighting operations and without the provision of appropriate equipment, both fire fighters and members of the public could be at a greater risk than perceived by current prescriptive documents. The Fire Brigade Intervention Model (FBIM) (5) provides a methodology that allows the designer to quantify the effects of a fire within a building on the responding fire fighters.

The FBIM, developed by the Australasian Fire and Emergency Services Authorities Council (AFAC), provides a methodology to assess fire brigade intervention and the impact of fire brigade operations on building designs. The FBIM has been in use for nearly a decade and is used regularly throughout Australia and to a lesser extent in New Zealand. Since November 2008 the FBIM has been referenced within the New Zealand compliance document C/AS1 (6) and is accepted by the NZFS as a suitable methodology to demonstrate the performance requirements of the NZBC relating to fire service operations. However, the FBIM is still a relatively new tool with no New Zealand data available to reflect NZFS operations. At present, building designs are using Australian data which is potentially dated and which has only undergone limited validation for New Zealand conditions. The data being used within the model may not, therefore, represent current NZFS operational practices or reflect the New Zealand fire environment.

The FBIM contains no New Zealand data and has not been scrutinised against NZFS standard operating procedures or local fire-fighting tactics that may differ from those employed by Australian brigades. This project aims to provide the statistical data to allow the FBIM to be used with confidence in New Zealand.

1.2. Aims and Objectives of this Research

The aim of this project is to collect the necessary data to populate the FBIM and to verify and validate the data against real incidents to enable the model to be used with confidence in New Zealand.

The collection, analysis and presentation of the data should also be sufficient to permit its use within a probabilistic risk assessment methodology and building design assessment methods.

It would be expected that the FBIM be used in building designs utilising performance-based designs or that contain aspects of alternative designs; examples include:

- performance-based fire engineering designs;

- buildings with large crowd occupancies or with extended evacuation times that will likely result in issues due to fire-fighter access contra-flow to occupant egress requirements;

- designs which fall outside of the scope of compliance documents or that have aspects of alternative designs which have a resultant affect on fire brigade intervention;

- buildings located in remote areas or in locations not serviced by fire brigades at the same level as that assumed by the compliance documents.

1.3. The Fire Brigade Intervention Model

In response to the introduction of a performance-based building code in Australia in 1996, AFAC formed a Performance-Based Fire Engineering Committee. The committee developed the FBIM so that fire brigades could ensure that their functional role was maintained in the Building Code of Australia.

The FBIM provides a formal structure for determining fire brigade intervention and operations within buildings. The FBIM is an event-based methodology, which quantifies fire brigade responses employed during a fire from time of notification through to control and extinguishment and overhaul. Detailed information is provided within the FBIM user manual available from AFAC (5). The FBIM time line is shown in Figure 1 incorporating the AFAC description of fire brigade intervention and operations (7).

Fire Brigade Intervention:

All fire agency activities from time of notification up to fire extinguishment and overhaul and includes fire brigade operations.

Fire Brigade Operations:

All fire-fighter activities from time of arrival at an incident including set up, search and rescue, fire attack, extinguishment and overhaul.

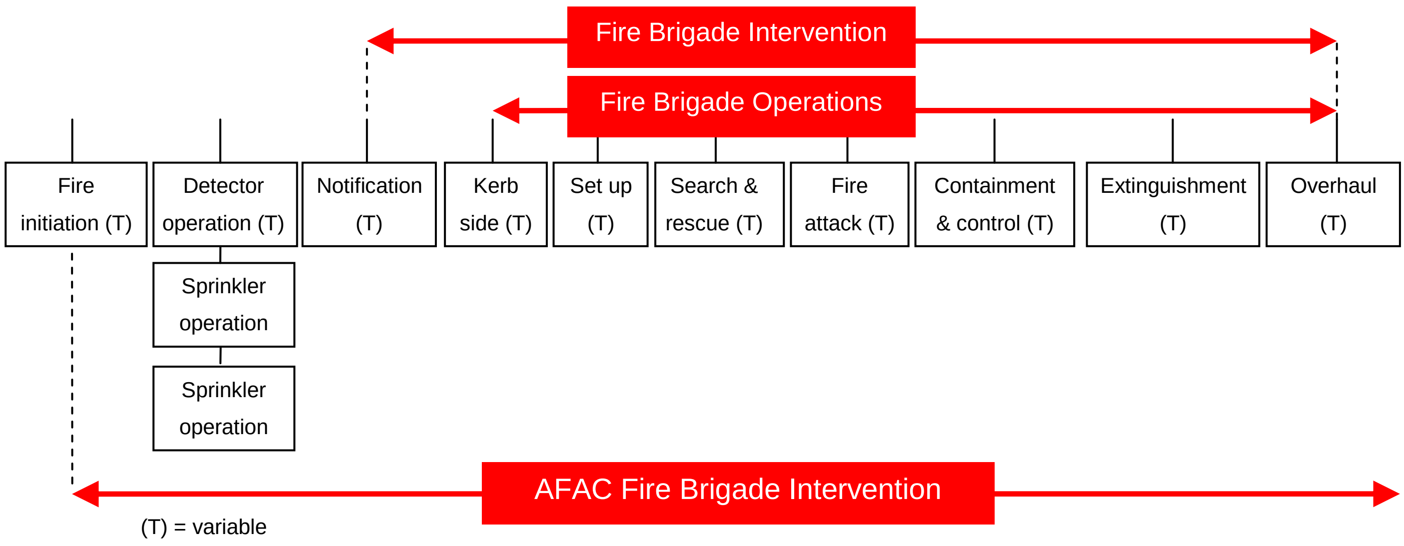

Figure 1 AFAC description of fire brigade intervention and operations (7)

The FBIM was developed for use in building designs so that the functional role of a fire brigade could be effectively incorporated into the building design process. It establishes a structured framework to quantify fire brigade activities on a time-line basis. The FBIM is carried out in conjunction with knowledge of typical fire engineering outputs such as fire growth, smoke and fire spread, detection and suppression as well as occupant evacuation. These outputs influence and modify the activities of the resources of the fire brigade at the fire scene and determine if additional resources are required.

An FBIM analysis allows the user to understand the times associated with each of the main critical factors that affect the overall time taken to undertake fire fighting operations within a building. Quantifying these issues informs the user on matters that affect both occupant and fire-fighter safety as well as property loss aspects of the design where they will be impacted upon by a responding fire brigade.

The FBIM relies on the completion of 16 flow charts to determine the sequence of events and the time taken to perform the relevant fire brigade activities specific to each scenario. Some of these tasks are sequential and some are parallel. The model establishes the critical path and thus the length of time to undertake fire brigade operations. Each flow chart represents a specific component of fire brigade intervention during a fire. The FBIM methodology is presented in the following flow chart (Figure 2) taken from the FBIM user manual (5).

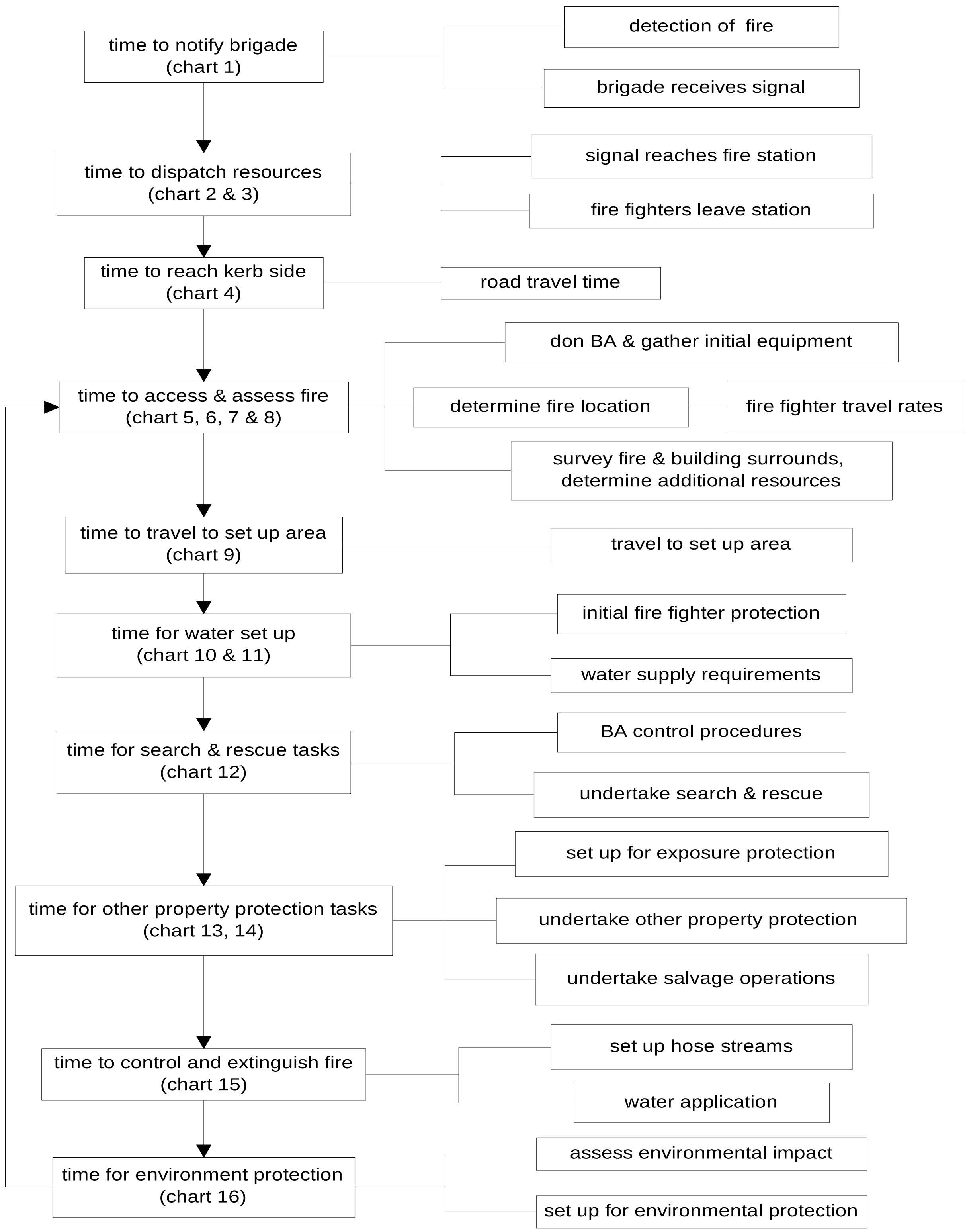

Figure 2 Fire Brigade Intervention Model overview (5)

1.4. Existing FBIM Data

To support each of the 16 FBIM charts, section 7 of the FBIM manual (5) provides 30 tables labelled A–Z providing statistical distributions and single values for the different times required to populate the model. Except for the five F series tables which provide the 'speed data for brigade travel' and are specific to specified brigades within the five different Australian states, all of the data provided is assumed to be representative of all Australian state fire brigade operational activities. No data currently provided within the FBIM manual was collected from the NZFS or has been verified against current NZFS operational procedures.

The data currently presented within the FBIM manual dates back prior to 1997 and was derived using various methods including literature review, statistical collation methods, measurement analysis, training practices and the Delphi method as described within the manual. Whilst the age of the data for most activities provided with an associated distribution is unlikely to have changed significantly over time, there is likely to have been a number of changes to both equipment and operating procedures that could have an effect on the accuracy of the data when applied to the current fire ground environment. Also, with there being known differences between the equipment used in Australia and New Zealand and with the potential for procedural differences between the respective brigades, the applicability of use of the existing FBIM data within New Zealand is uncertain.

The FBIM computer program user manual (8) provided to aid implementation of the FBIM further identifies that the model relies on applicable data specific to the attending fire brigade:

> *"The fire brigade intervention model relies upon applicable data, which may be obtained from the fire brigade fire safety department of the brigade that will attend the property in question."*

As the NZFS has no supporting FBIM data, the NZFS have, to date, been recommending the use of the FBIM manual data for generic operational tasks and the brigade travel times associated with the Melbourne Fire Brigade.

The FBIM computer program user manual provides five different general uses or "run strategies" as examples of the level of analysis which can be undertaken to support fire brigade intervention strategies. These run strategies list the extent of data required to support each strategy and include the following:

- *Kerbside arrival*
    - *This includes the time for the fire brigade units to respond to a call and arrive at the fire scene, represented by Charts 1-4.*
- *Fire brigade arrival and set-up*
    - *The time at which the fire brigade will arrive at the fire scene, represented by Charts 1-11.*
- *Search and rescue*
    - *fire brigade arrival time including the time taken for search and rescue operations to be conducted, represented by Charts 1-12.*
- *Protect exposure*
    - *the time taken for exposure protection to be setup but not completed, represented by Charts 1-13.*
- *Other strategies*
    - *Including the time taken for exposure protection to be completed and other aspects of fire brigade operations including property protection and protection of the environment. These strategies are completed using Charts 1-16.*

From the above and lack of NZFS data it can be seen that even the most basic FBIM analysis – *kerbside arrival*, would produce uncertain results when used in New Zealand. This project aims to collect and validate the required data to support any FBIM analysis or fire brigade intervention strategy desired. The following chapters in this project aim to provide relevant information and NZFS-specific data to support and validate the use of the FBIM and fire brigade operational analysis within performance-based designs.

CHAPTER 2. Fire-Fighting Needs and Building-Design Requirements in New Zealand

2.1. Introduction

Building designs have traditionally been required to provide sufficient facilities to support fire fighting operations based on the requirements of the attending fire brigades. These requirements are dependent on their level of resources, equipment type and methods employed when fighting fires. In New Zealand these have historically followed on from those predominately established in the United Kingdom. Assumptions regarding fire brigade attendance and the implications this has on building design has been evident for decades in guidance documents such as the UK Post War Building Studies published in 1952 (9). Any fire brigade operations in buildings will be reliant on the limitations provided by the equipment being used and the fire fighters who themselves have limitations on their ability to perform for extended durations in the fire environment. Prescriptive building design requirements have traditionally recognised the limitations of fire fighters by requiring sufficient facilities internally and externally to the building to facilitate their needs. These have included access requirements to building perimeters, the provision of internal fire-fighting equipment and access provisions to support expeditious fire-fighting activities in places of relative safety.

To ensure that the needs of the fire service are provided within a building using performance-based design methods, an understanding of the responding fire brigade and relevant legislation must exist. Only with an understanding of fire brigade operations and how a fire brigade uses the fire-fighting facilities provided within buildings, together with legislative requirements, can a designer ensure that the level of safety provided to the building, its occupants, fire fighters and the environment is provided at least to the same level as that implicit within the NZBC performance requirements. Therefore, an understanding of the legislation that drives the requirements for both the fire brigades and the building design must be understood. The Building Act of 1991 which introduced performance-based design, consolidated a wide range of building legislation and simplified building construction requirements. The 1991 Act has since been superseded for various reasons, but of significance was the introduction of the NZFS into the building design review process within the 2004 Act. The following sections provide a brief introduction to the NZFS, the Fire Service Act (1975) and the Building Act, Building Regulations and NZBC and how they impact on the design requirements in a performance-based building environment. It should, however, be noted that any additional requirements set out within the legislation such as the Fire Safety and Evacuation of Buildings Regulations 2006 and the Hazardous Substances and New Organisms Act 1996 are not covered below.

2.2. New Zealand Fire Service Introduction and Legislation

Two separate statutes, the Fire Service Act 1975 and the Forest and Rural Fires Act 1977, establish the governance, management and operational arrangements for protecting life and property from fire in New Zealand. From a fire-fighting perspective, the fire environment in New Zealand consists of two distinct categories: the built environment, known as urban fire districts (UFD) and the land environment, or rural fire districts (RFD). UFD typically include those areas containing industrial, commercial and residential structures, community infrastructure and social amenities. RFD comprise large areas of cultivated crops, plantation forestry, forest and land reserved for conservation. RFD also include isolated dwellings and rural amenities.

Inside UFD responsibility for the prevention, suppression and extinction of all classes of fires rests with the national commander of the NZFS and the chief fire officer of the fire district. UFD are covered by a single national agency (NZFS) responsible for emergency response across almost all urban areas, The NZFS currently comprises the following resources.

- 345 gazetted UFD, each with a statutory officer authorised to exercise prescribed powers within the fire district.
- 436 fire stations and their associated plant and equipment.
- Approximately 1,700 career firefighters, 8,000 volunteer firefighters, 85 specialist fire safety officers and 10 professional fire engineers.
- 800 fire appliances and operational response equipment for dealing with fires and other emergencies.
- Three communication centres with 75 staff who receive emergency calls from the 111 system and private fire alarm monitoring systems and dispatch resources from local fire stations to emergencies.
- A national headquarters located in Wellington; eight regional offices and 25 area offices located around New Zealand to provide leadership and support services via 360 management and support staff to fire stations.

Within RFD, responsibility for managing all types of fire rests with the relevant rural fire authority. Rural fire authorities include territorial authorities, the Department of Conservation, the New Zealand Defence Forces and special purpose collectives of the aforementioned entities together with plantation forest companies. There are 86 rural fire authorities who are responsible for response to vegetation wildfires in association with the NZFS who can respond to non-fire emergencies and fires in a RFD. The work of these rural fire authorities is coordinated by the office of the National Rural Fire Authority (NRFA).

The NRFA currently comprises the following resources:

- The national rural fire officer and five regional rural fire managers.
- National fire weather monitoring system.
- National alerting capability through the three communication centres shared with the UFD.
- Three national incident management teams.
- Funding for grants to fire authorities for equipment and appliances.

As this project is primarily focused on urban built environment issues no further detail on the Forest and Rural Fires Act 1977 is provided.

2.2.1. Fire Service Act 1975

The NZFS is governed by the Fire Service Act 1975. This Act places specific functions on the NZFS including those concerning the protection of life and property as set out within section 28 of the Act:

28. Functions, duties, and powers of Chief Fire Officer

(2) In the event of any alarm of fire or any fire happening, the Chief Fire Officer of the Fire District, or in his or her absence, the Deputy Chief Fire Officer, or, in the absence of both of them, the person for the time being in charge of the fire service, shall forthwith proceed, or direct some other member of the brigade to proceed forthwith, to the place to which the brigade has been called, and endeavour by all practicable means to extinguish and prevent the spread of the fire (if any), and to save lives and property in danger.

Whilst this Act does not specifically require protection of the environment; NZFS policies require that protection of the environment be afforded and taken into account and recognised within fire-fighting operations, including such issues as fire-fighting run-off water and discharges made at fires.

2.3. Building Act 2004

Requirements of the Building Act surrounding fire-fighting needs are central to the FBIM and its implementation. Of significance is that the Act specifically recognises fire fighters as occupants of a building and that the building must be durable for its intended use which includes the life safety of fire fighters during fire emergencies.

> ***Part 1 Preliminary provisions***
>
> ***4. Principles to be applied in performing functions or duties, or exercising powers, under this Act***
>
> *(2) In achieving the purpose of this Act, a person to whom this section applies must take into account the following principles that are relevant to the performance of functions or duties imposed, or the exercise of powers conferred, on that person by this Act:*
>
> > *(c) the importance of ensuring that each building is durable for its intended use:*

The Building Act goes on to define **intended use** in relation to a building as:

> > *(a) includes any or all of the following:*
> >
> > > *(iii) activities undertaken in response to fire or any other reasonably foreseeable emergency;*

However, the most relevant section of the Act pertaining to fire service operations is section 4(2)(h) that states that one such principle that must be applied is:

> *“The reasonable expectations of a person who is authorised by law to enter a building to undertake rescue operations or fire fighting to be protected from injury or illness when doing so”*.

It should be noted that ‘reasonable’ in this case relates to the expectations of the fire fighter to be protected, and not, as many designers would have it, to whether or not the fire fighter should enter the building. This emphasises the fact that the performance requirements of the NZBC C3.3.9 are mandatory, and that designers must therefore give them due consideration when preparing a fire engineering analysis for any building.

Section 16 and 17 in part 2 of the Act requires that building work must comply with the NZBC.

> ***Part 2 Building***
>
> ***s16 Building code: purpose***
>
> *The Building Code prescribes functional requirements for buildings and the performance criteria with which buildings must comply in their intended use.*
>
> ***s17 All building work must comply with building code***
>
> *All building work must comply with the Building Code to the extent required by this Act, whether or not a building consent is required in respect of that building work.*

2.4. New Zealand Building Code

New Zealand was one of the first countries to adopt a performance-based building code in 1992. Before this time, prescriptive building requirements describing how a building must be designed and constructed were set out within a model building bylaw known as ‘NZS1900’ Chapter 5 (10). NZS 1900 was adopted and enforced by most local authorities prior to the introduction of the 1991 Building Act. Contrary to prescriptive regulations, a performance-based code states how a building and its components must perform. A performance-based approach is therefore intended to provide flexibility, innovation and uniqueness and with specific regard to fire safety should offer benefits that a prescriptive code cannot provide for, these include:

- allowing for innovative design;
- an overall higher standard of fire safety in buildings;
- allowing for the safety levels for alternative designs to be compared;
- providing a basis for selection of appropriate fire protection systems;

- flexibility of choice and specification leading to cost-effective fire safety and protection measures;
- increased and better communication with the stakeholders involved in the design and construction process, including the emergency services;
- maximising efficiencies through eliminating redundant safety features whilst maintaining safety standards.

As with most performance-based building codes, the structure of New Zealand's Building Code specifies a specific objective of the code and sets performance requirements that must be followed to demonstrate compliance with the code. The structure of the NZBC is set out below as given by the Department of Building and Housing (DBH) (11).

The NZBC consists of two preliminary clauses and 35 technical clauses. Each technical clause contains:

> ***An objective*** – *the social objective that completed building work must achieve*
>
> ***A functional requirement*** – *what the completed building work must do to satisfy the social objective*
>
> ***Performance criteria*** – *qualitative or quantitative criteria which nominates how far the completed building work must go in order to comply.*

The Act requires that all building work must satisfy the NZBC and must comply with the performance requirements of the Code. Demonstrating compliance with the code can therefore be done by any means. Compliance documents establish one method of complying with these performance requirements, the other is by way of an alternative solution. These two compliance paths are discussed further in sections 2.5 and 2.6.

Selected parts specifically relating to the fire brigade intervention requirements of the NZBC follow (where words in italics are specifically designed terms).

> **Clause C2—MEANS OF ESCAPE**
>
> OBJECTIVE
>
> C2.1 The objective of this provision is to:
>
> (b) Facilitate *fire* rescue operations.

FUNCTIONAL REQUIREMENT

C2.2 Buildings shall be provided with means of escape from fire which:

(b) Give Fire Service personnel *adequate* time to undertake rescue operations.

PERFORMANCE

C2.3.1 The number of *open paths* available to each person escaping to an *exitway* or *final exit* shall be appropriate to:

(d) The fire safety systems installed in the firecell.

C2.3.2 The number of *exitways* or *final exits* available to each person shall be appropriate to:

(e) The fire safety systems installed in the building.

Clause C3–SPREAD OF FIRE

OBJECTIVE

C3.1 The objective of this provision is to:

(b) Provide protection to Fire Service personnel during firefighting operations.

FUNCTIONAL REQUIREMENT

C3.2 *Buildings* shall be provided with safeguards against *fire* spread so that:

(b) Fire fighters may undertake rescue operations and protect property,

PERFORMANCE

C3.3.1 Interior surface finishes on walls, floors, ceilings and suspended *building elements*, shall resist the spread of *fire* and limit the generation of toxic gases, smoke and heat, to a degree appropriate to:

(d) The active *fire safety systems* installed in the *building*.

C3.3.9 The *fire safety systems* installed shall facilitate the specific needs of Fire Service personnel to:

(a) Carry out rescue operations, and

(b) Control the spread of *fire*.

> **Clause C4—STRUCTURAL STABILITY DURING FIRE**
>
> FUNCTIONAL REQUIREMENT
>
> C4.2 Buildings shall be constructed to maintain structural stability during fire to:
>
> (b) Allow fire service personnel adequate time to undertake rescue and firefighting operations.
>
> PERFORMANCE
>
> C4.3.1 Structural elements of buildings shall have fire resistance appropriate to the function of the elements, the fire load, the fire intensity, the fire hazard, the height of the buildings and the fire control facilities external to and within them.

The most explicit performance requirement relating to the fire brigade is that of C3.3.9. The term 'fire safety systems' is defined in the Building Regulations as *"The combination of all methods used in a building to warn people of an emergency, provide for safe evacuation, and restrict the spread of fire, and includes both active and passive protection"*. This definition has the same meaning and wording as the definition of 'fire safety precautions' in C/AS1.

Otherwise, the other requirements only relate to the *fire safety systems* required to be installed. It is also noted that there are no performance requirements specific to fire brigade intervention required to meet clause C4 of the NZBC. However, this does not imply that structural fire ratings are not required to facilitate fire brigade operations as *fire control facilities* are considered to include the fire service. This can be seen in Determination 2001/5 (12) in which the Building Industry Authority (BIA), later replaced by the Department of Building and Housing (DBH), referred to both NZBC Clause C3.3.9 and to Clause C4.3.1 when dealing with the matter of protecting fire fighters from structural collapse. Clause C4.3.1 states that:

> *Structural elements of buildings shall have fire resistance appropriate to the function of the elements, the fire load, the fire intensity, the fire hazard, the height of the buildings and the fire control facilities external to and within them.*

The BIA took the view that C4.3.1 required such fire resistance to be appropriate to the function of allowing fire brigade personnel adequate time to undertake fire-fighting operations. The BIA did not accept that the life of a fire fighter is to be safeguarded only while the fire fighter is undertaking rescue operations or protecting household units or other property. The determination stated that it was enough that the fire fighter was in or around the building for the purpose of activities taken in response to fire or other emergencies as mentioned in the definition of "intended use". The BIA concluded that in order to comply with the building code, the building elements concerned must have fire resistance ratings appropriate for the protection of fire fighters. That does not necessarily mean that the ratings must be those specified in the Acceptable Solution and indicated that an appropriate analysis could demonstrate that lower fire resistance ratings could meet the performance requirements of the NZBC.

2.5. The Acceptable Solution, C/AS1

The Acceptable Solution C/AS1 (6) provides a means of complying with the fire safety requirements of the NZBC. Section 8 of C/AS1 is specific to fire fighting and contains provisions for fire-fighting facilities including, specifically, vehicular access, internal fire hydrants, hose reels, fire systems centres, lift control and communication systems. However, requirements specific to fire brigade intervention can also be found throughout the remaining parts of C/AS1. Clear examples include the limitations on fire cell floor areas in clause 4.2.3 which are required to '*assist fire-fighting operations'*. Other clauses of the document also make assumptions based on the ability of the fire service to intervene effectively as can be seen within the comment to clause 7.3.15. This comment states that radiation criteria used to control external fire spread within the said document are based on the historic ability of the fire service to control fires and prevent external fire spread, indicating that C/AS1 assumes a minimum level of attendance and availability of the fire service. Another well known requirement relating specifically to fire service limitations is the restriction on single internal escape routes for buildings over 25 m (cl.3.15.3). This limitation was originally based on the limited ability of the fire service to enter buildings externally and was derived from the limitations of fire appliances with 100 ft ladders (13). It is interesting to note that modern fire aerial appliances are typically still specified on the basis that they only need to reach to buildings constructed up to this height.

Other than the International Fire Engineering Guidelines (IFEG) (14) no direct reference to the FBIM existed within the NZBC or compliance documents prior to November 2008. However, the latest amendment to C/AS1 specifically references the use of the FBIM and was a significant step on behalf of the DBH in recognising the FBIM. The FBIM comment specifically relates to requirements for large unsprinkled fire cells in clause 4.2.4:

COMMENT:

Roof venting systems such as drop-out panels, louver vents or ridge venting shall be designed and proven for the purpose of facilitating firefighting operations. The Australasian Fire and Emergency Services Authorities Council's Fire Brigade Intervention Model (www.afac.com.au/awsv2/ learning/fbim.htm) provides guidance on performance criteria for fire fighters. Less than 15% roof area for venting may be acceptable if total system performance can be demonstrated.

It is also important to note that within the scope of C/AS1, clause 1.1.2 states that it is appropriate for *'simple, low rise buildings*.' It therefore needs to be questioned how applicable the compliance document is, especially with respect to fire-fighting facilities when dealing with design of buildings that are not *'simple, low rise buildings*.'

The Acceptable Solution C/AS1 is currently undergoing a major review and is expected to address some of the issues raised within this project.

2.6. Alternative solutions

The Department of Building and Housing (DBH) provides guidance on what constitutes alternative solutions (or specific design) on its website (15). It states that:

An alternative solution is a building design, of all or part of a building, that demonstrates compliance with the Building Code. It can include a material, component or construction method that differs completely or partially from those described in the Compliance Documents.

As C/AS1 is not a mandatory document, the DBH endorses the use of the IFEG for guidance on appropriate process and methodology for developing and reporting fire engineering Alternative Solutions. The DBH released the IFEG in 2005 as a guidance document under section 175 of the Building Act 2004 (16). The IFEG provides a process for developing fire-engineering solutions using international best practice which has also been endorsed by the NZFS and the Institute of Professional Engineers New Zealand. These documents provide a process to undertake fire engineering and methodologies that can be used, including the FBIM. Within New Zealand the IFEG has also been recommended as the basis '*for all fire* *engineering design work'* (17). Both the IFEG and DBH provide a number of approaches and methods of analysis including:

- comparative or absolute;
- qualitative or quantitative;
- deterministic or probabilistic.

For compliance with the fire safety requirements of the NZBC it is typical for alternative solutions to only consider minor alterations from the requirements of the compliance documents. It is rare for designs produced in New Zealand to be derived from a total performance approach and/or to deviate significantly from the compliance documents. Therefore, it is common to see the identified non-compliance aspects reviewed in isolation from the other requirements of the compliance documents. This is problematic in itself as most prescriptive requirements have been derived or based on assumptions about the interaction and effectiveness of the other requirements. Little or, in most cases, no guidance or explanation is provided to explain what formed the basis of the requirements or what impact changing or removing them would have on the remaining design aspects.

2.7. Determinations

The NZFS maintains that the prescriptive compliance documents provide a benchmark as to the level of safety required to achieve the performance requirements of the NZBC. In Determinations taken by the NZFS, concerns have been raised and upheld by the DBH that designs have ignored fire fighters as occupants of the building within the alternative designs put forward. As well as Determination 2001/5 (18), another recent example includes Determination 2009/100 (19) regarding the structural stability of a high-rise office building. Within this determination it specifically notes NZFS concerns regarding the proposed structural fire ratings and their relationship to fire-fighter safety:

> *"Allowing C6.10.5 to take precedence takes absolutely no account of what is above the car park, and therefore fails to recognise any consequences of structural failure in terms of the threat to the life of occupants, people in the vicinity and, most particularly, fire-fighters."*

CHAPTER 3. A Statistical Review of Fire Engineering Designs Submitted to the NZFS with respect to Fire-Fighting Facilities

3.1. Introduction

This chapter provides the statistics associated with the Building Consent applications reviewed to date by the NZFS Design Review Unit (DRU) specifically with regards to the assessment of fire-fighting facilities. They are intended to support the ongoing concerns that have been raised in New Zealand and internationally regarding the impact of fire engineering on fire service needs and to support the need for the use of the FBIM together with the research presented herein.

The Building Act 2004 requires that certain building consent applications be provided to the NZFSC and enables the Commission to provide advice to Building Consent Authorities with respect to the following matters:

(a) provisions for means of escape from fire;

(b) the needs of persons who are authorised by law to enter the building to undertake fire fighting.

The NZFSC were included in the 2004 Act for a number of reasons, one of which included ensuring that departures from the compliance documents relating to fire-fighting facilities were approved by the NZFSC and not the Building Consent Authorities (20). This work is undertaken for the NZFSC by the DRU.

The DRU was established in 2005 and began reviewing building consent applications on 22nd April of that year. Before this time, information regarding the design of fire-fighting facilities in buildings was unknown and due to the nature of building consent processing, unquantifiable. The DRU receives and reviews on average 48 building consent applications a month. At the time of writing this report, approximately 3,000 designs had been reviewed by the DRU, of which 1,200 have been specifically reviewed in this project for the purposes of gaining statistics relating to fire-fighting facilities.

Additional findings are also presented which potentially impact on fire brigade operations on a holistic basis. For example, where the DRU has provided recommendations with regards to any structural analysis it considers is insufficient or where computer modelling has been undertaken and recommendations made, these statistics have also been collected and presented.

3.1.1. Data Collection

The statistics presented within this report have been collated using simplistic yes/no sampling. All of the DRU memorandums produced have been specifically reviewed to ascertain whether any recommendations have been made that have an effect on fire brigade operations. This includes issues specific to fire-fighting facilities and also issues that may have a detrimental effect on the ability of the NZFS to undertake its statutory functions including search and rescue and fire fighting. Statistics relating to fire-fighting facilities have been collected based on the recommendations provided to Building Consent Authorities within the DRU memorandums. The statistics have been broken down into five categories which reflect the main requirements of fire-fighting facilities within the compliance documents, C/AS1.

1. Recommendations regarding and taking into account any fire-fighting facilities that have been commented upon. This includes any recommendations that the DRU has provided that specifically affect fire-fighting operations, such as the provision of fire service lift controls, fire cell size limitations etc. These figures include other recommendations that have been specifically identified and segregated, including:

2. Recommendations specifically regarding the provision of building fire hydrants.

3. Recommendations specifically regarding the requirements for vehicle access which incorporates the identification of any attendance points including the location of Fire Alarm Panel (FAP) locations. Vehicular access and alarm panel requirements have been captured together as typically identification of the placement of a FAP placement infers the location of any attendance point and vice versa.

4. Submissions where no information at all regarding fire-fighting facilities is provided but considered necessary by the DRU to demonstrate compliance with the requirements of the NZBC.

Fire reports often provide no details whatsoever regarding fire-fighting facilities. For new buildings, such requirements are necessary, but this is not always the case for certain buildings undergoing minor alternations, not affecting fire-fighting requirements.

To capture the holistic aspects of building design another category has been provided which includes:

5. Submissions where the DRU considered that the documentation contained insufficient information to demonstrate compliance with the NZBC with regards to any aspect of compliance.

3.2. Findings

3.2.1. DRU Building Consent Applications by Type

Building consent applications can be divided into three categories requiring different levels of DRU review in accordance with the Act. It is important to recognise the effect that these different requirements place on the consideration of fire-fighting needs and specific facilities as existing buildings may not need consideration of fire-fighting facilities to the same extent as new buildings. This factor would need to be recognised within any FBIM assessment so these statistics have been separated into the different categories dependent on the requirements placed upon it by the Building Act.

The different requirements include:

- New building work assessed in accordance with s.17 of the Act. S.17 requires all new building work to comply with all clauses of the NZBC.

- Existing buildings undergoing a *Change of Use* assessed in accordance with s.115 (b) of the Act.

- Existing buildings undergoing alterations assessed in accordance with s.112 of the Act.

For existing buildings undergoing a *Change of Use*, s.115 of the Act requires that such buildings comply with the NZBC aspects that relate to means of escape from fire, protection of other property, sanitary facilities, structural performance and fire-rating performance only.

Fire-fighting facilities are required to be considered under s.115 of the Act only where their provision relates to the means of escape from fire, protection of other property, structural performance or the fire-rating performance of the building.

For buildings undergoing alterations, there are further subcategories which need to be considered with respect to how the consent application should be assessed.

- Existing buildings undergoing alterations assessed in accordance with s.112 (1) of the Act.

- Existing buildings undergoing alterations and additions assessed in accordance with s.112 of the Act. It should be noted that the NZFS typically undertakes assessment of additions in accordance with s.17 of the Act

- Existing buildings undergoing alterations assessed in accordance with s.112 (2) of the Act. It should be noted that alterations undertaken in accordance with s.112 (2) of the Act need not comply with the requirements of the NZBC if:

  (a) the building was required to comply with the relevant provisions of the building code, the alteration would not take place; and

  (b) the alteration will result in improvements to attributes of the building that relate to:

  (i) means of escape from fire; or

  (ii) access and facilities for persons with disabilities; and

  (c) the improvements referred to in paragraph (b) outweigh any detriment that is likely to arise as a result of the building not complying with the relevant provisions of the building code.

It is important to note that buildings undergoing alterations are only required to comply, *'as nearly as is reasonably practicable'* with the provisions of the NZBC that relate to the means of escape from fire and access and facilities for persons with disabilities. Fire-fighting facilities not related to the means of escape from fire do not require assessment and are not commented on by the DRU and may not need to be factored into any FBIM assessment.

Collation of statistics from the DRU memorandums is ongoing. To date, over 1200 (approximately 42%) of the consents received have been reviewed. Figure 3 summarises the breakdown by type of consent applications submitted to the DRU.

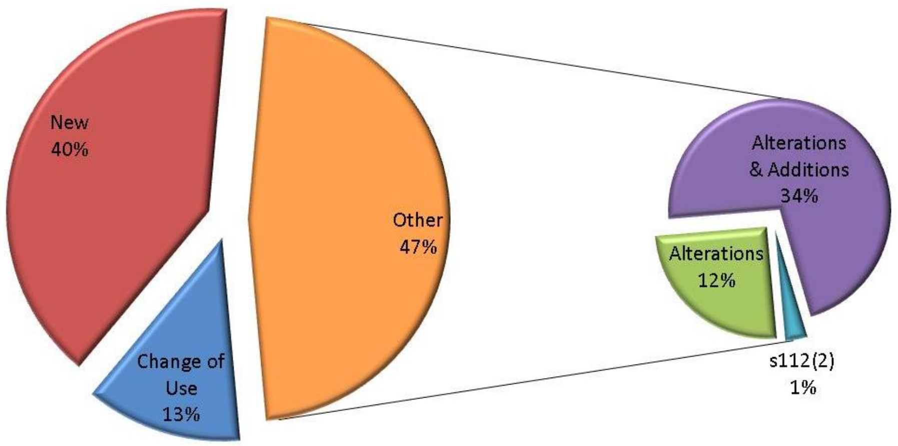

Figure 3 DRU consent type breakdown

The breakdown of Building Consent applications by type assessed by the DRU is as follows:

- new (proposed) buildings accounted for 40% of submissions;
- existing buildings undergoing a Change of Use accounted for 13;
- existing buildings undergoing an Alteration accounted for 47%.

Of the 47% of applications for buildings undergoing alterations for all submissions:

- existing buildings undergoing an Alteration accounted for 12%;
- existing buildings undergoing an Alteration including Additions accounted for 34%;
- existing buildings undergoing an Alteration considered to be an upgrade accounted for 1%.

For all consent applications, the DRU provided recommendations in 86% of all the submissions. From this it could be concluded that the DRU considered that the design information submitted for review had demonstrated compliance with the relevant performance requirements of the NZBC in 14% or approximately 170 of the submissions.

The associated breakdown of memorandums considered to demonstrate compliance with the relevant performance requirements of the NZBC by the DRU is shown in Figure 4.

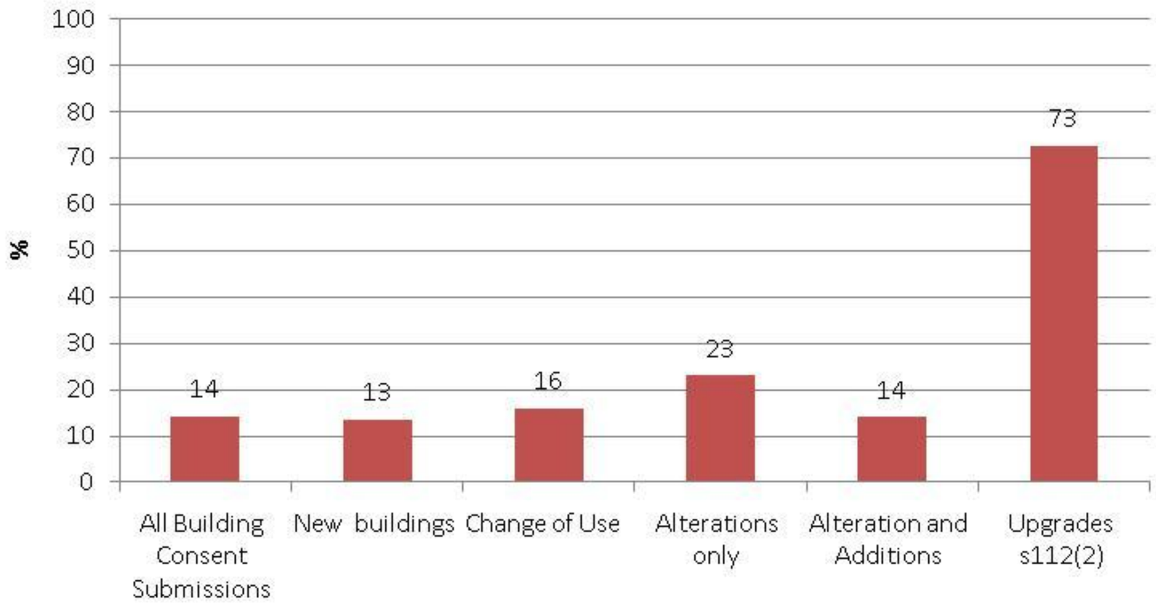

Figure 4 DRU memorandums provided with no recommendations

The percentage of DRU memorandums in which no recommendations were provided is as follows:

- all Building Consent submissions – 14%;
- new (proposed) buildings – 13%;
- existing buildings undergoing a Change of Use – 16%;
- existing buildings undergoing an Alteration:
    - Alterations only – 23%;
    - Alteration and Additions – 14%;
    - Upgrades s.112(2) – 73%.

The DRU also considered that there was not enough information provided to establish and demonstrate compliance with the NZBC in 67% of all submissions. Information indentifying that insufficient information has been provided is shown for each of the consent types in the following section.

3.3. Fire-fighting Facilities

This section provides the statistics specifically relating to fire-fighting facilities identified in DRU memorandums.

3.3.1. All Submissions

Statistics from all DRU memorandums specific to fire-fighting facilities are shown in Figure 5.

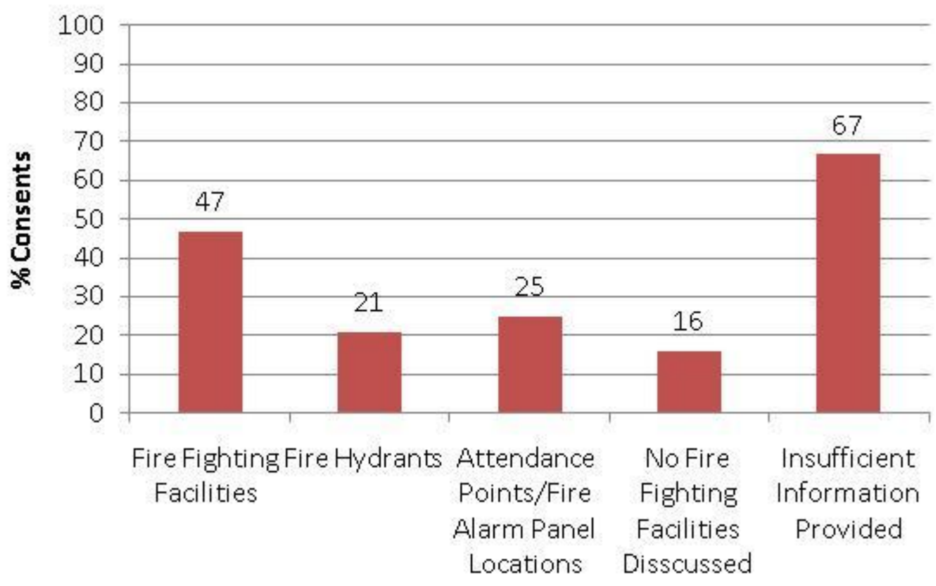

Figure 5 Fire-fighting facilities questioned within all DRU memorandums

Analysis of the DRU memorandums produced the following findings.

- Recommendations regarding fire-fighting facilities were made in 47% of memorandums.
- Recommendations regarding fire hydrants were made in 21% of memorandums.
- Recommendations regarding attendance points including FAP locations were made in 25% of memorandums.
- Of significant concern is that in 16% of all submissions, no information at all regarding fire-fighting facilities was provided, but was considered necessary to demonstrate compliance with the NZBC.
- Sixty-seven percent contained advice stating that the documentation contained insufficient information to demonstrate compliance with the NZBC and recommended that further information be supplied.

3.3.2. New Buildings

Statistics from DRU memorandums for new buildings specific to fire-fighting facilities are shown in Figure 6.

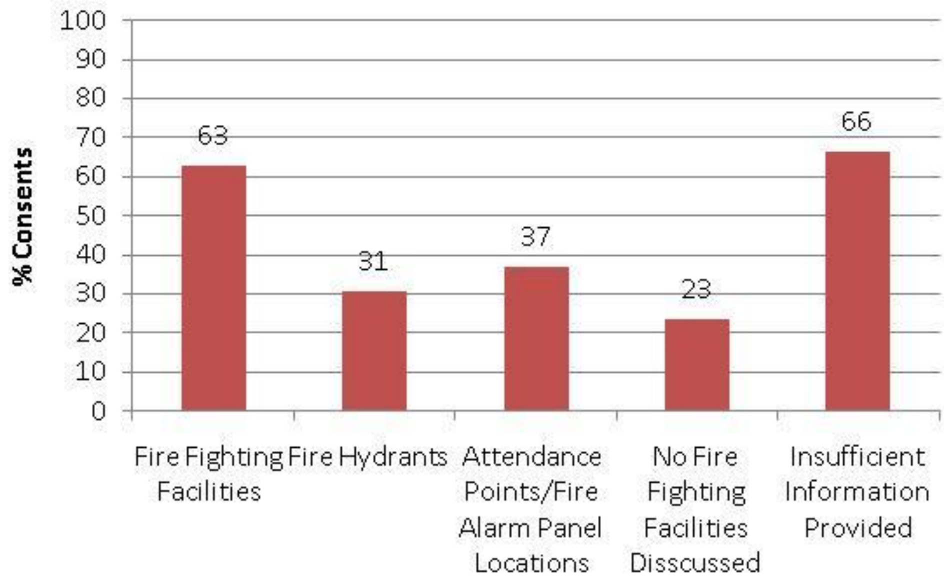

Figure 6 Fire-fighting facilities questioned within DRU memorandums for new buildings

Analysis of the DRU memorandums for new buildings produced the following findings.

- Recommendations regarding fire-fighting facilities were made in 63% of memorandums.
- Recommendations regarding fire hydrants were made in 31% of memorandums.
- Recommendations regarding attendance points including FAP locations were made in 37% of memorandums.
- In 23% of all submissions for new buildings, no information at all regarding fire-fighting facilities was provided.
- Sixty-six percent contained advice stating that the documentation contained insufficient information to demonstrate compliance with the NZBC and recommended that further information be supplied.

3.3.3. Buildings Undergoing a Change of Use

Statistics from DRU memorandums for buildings undergoing a Change of Use specific to fire-fighting facilities are shown in Figure 7.

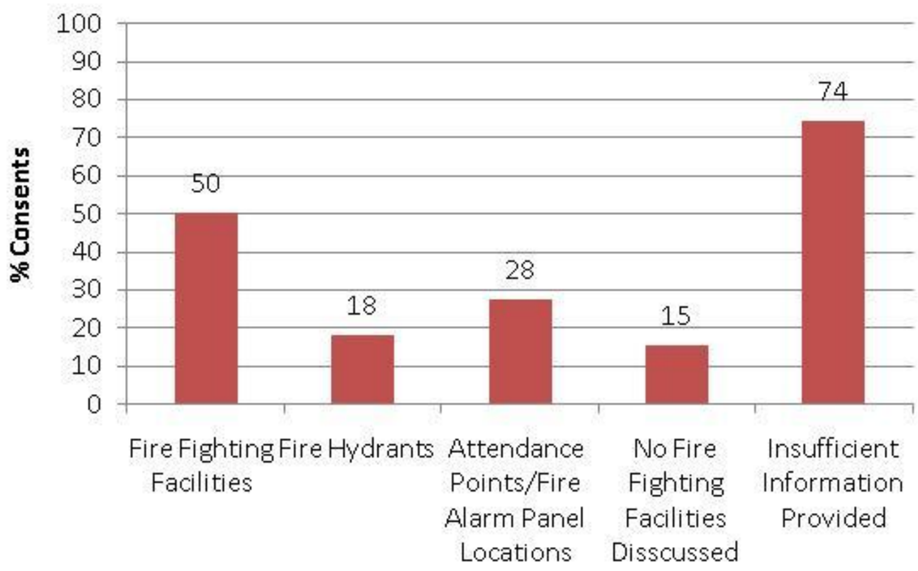

Figure 7 Fire-fighting facilities questioned within DRU memorandums for buildings undergoing a Change of Use

Analysis of the DRU memorandums for buildings undergoing a Change of Use produced the following findings.

- Recommendations regarding fire-fighting facilities were made in 50% of memorandums.
- Recommendations regarding fire hydrants were made in 18% of memorandums.
- Recommendations regarding attendance points including FAP locations were for new buildings in 28% of memorandums.
- In 15% of all submissions, no information at all regarding fire-fighting facilities was provided.
- Seventy-four percent contained advice stating that the documentation contained insufficient information to demonstrate compliance with the NZBC and recommended that further information be supplied.

3.3.4. Buildings Undergoing Alterations

3.3.4.1. Alterations Only

For existing buildings undergoing Alterations only, fire-fighting facilities are not specifically required to be considered under s.112 of the Act. However, where such fire-fighting facilities are considered to be relevant to the means of escape from a building, such as when fire-fighting facilities are provided to support NZFS search and rescue operations, the DRU will provide comment as considered necessary. These figures are shown in Figure 8.

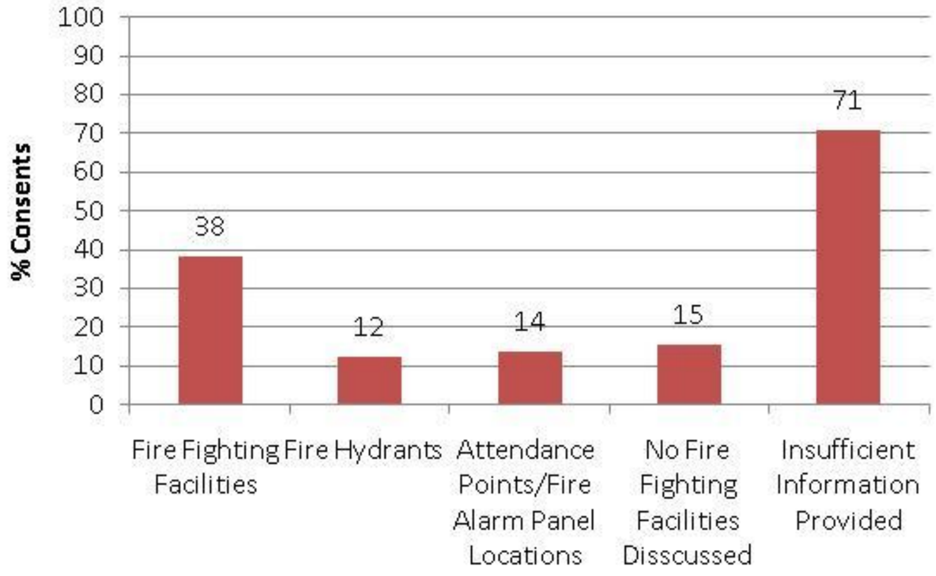

Figure 8 Fire-fighting facilities questioned within DRU memorandums for buildings undergoing an Alteration

Analysis of the DRU memorandums for buildings undergoing Alterations produced the following findings.

- Recommendations regarding fire-fighting facilities were made in 38% of memorandums.
- Recommendations regarding fire hydrants were made in 12% of memorandums.
- Recommendations regarding attendance points including FAP locations were made in 14% of memorandums.
- In 15% of all submissions, no information at all regarding fire-fighting facilities were provided.

- Seventy-one percent contained advice stating that the documentation contained insufficient information to demonstrate compliance with the NZBC and recommended that further information be supplied.

3.3.4.2. Alterations and Additions

For buildings undergoing Alterations and Additions, where significant additions should be treated as for new buildings and comply with all the requirements of the NZBC, issues specific to fire-fighting facilities are shown in Figure 9.

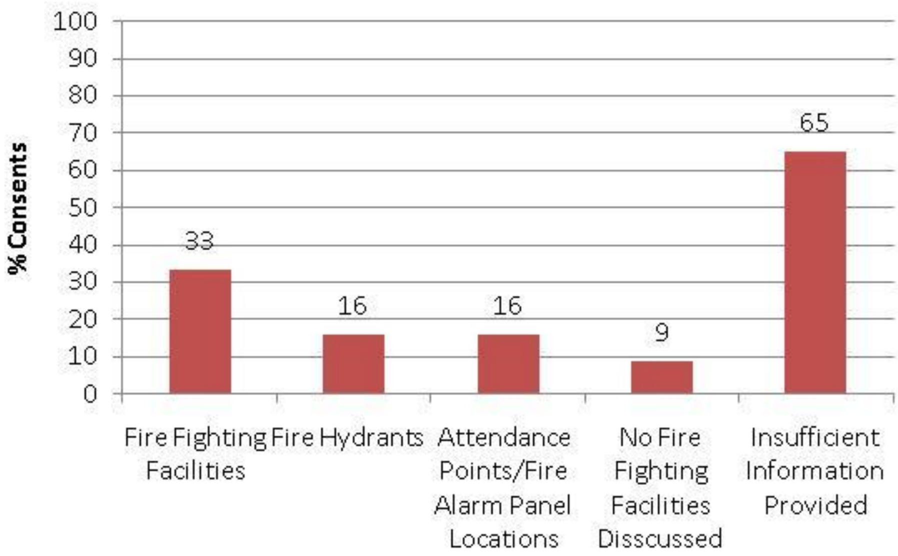

Figure 9 Fire-fighting facilities questioned within DRU memorandums for buildings undergoing Alterations including an Addition

Analysis of the DRU memorandums for buildings undergoing Alterations and Additions produced the following findings.

- Recommendations regarding fire-fighting facilities were made in 33% of memorandums.
- Recommendations specifically regarding fire hydrants were made in 16% of memorandums.
- Recommendations specifically regarding attendance points including FAP locations were made in 16% of memorandums.

- In 9% of all submissions, no information at all regarding fire-fighting facilities were provided.
- Sixty-five percent contained advice stating that the documentation contained insufficient information to demonstrate compliance with the NZBC and recommended that further information be supplied.

3.3.4.3. Alterations Considered as Upgrades

For buildings undergoing Alterations and treated in accordance with s.112 (2) of the Act and considered to represent upgrades to the building, issues specific to fire-fighting facilities are shown in Figure 10.

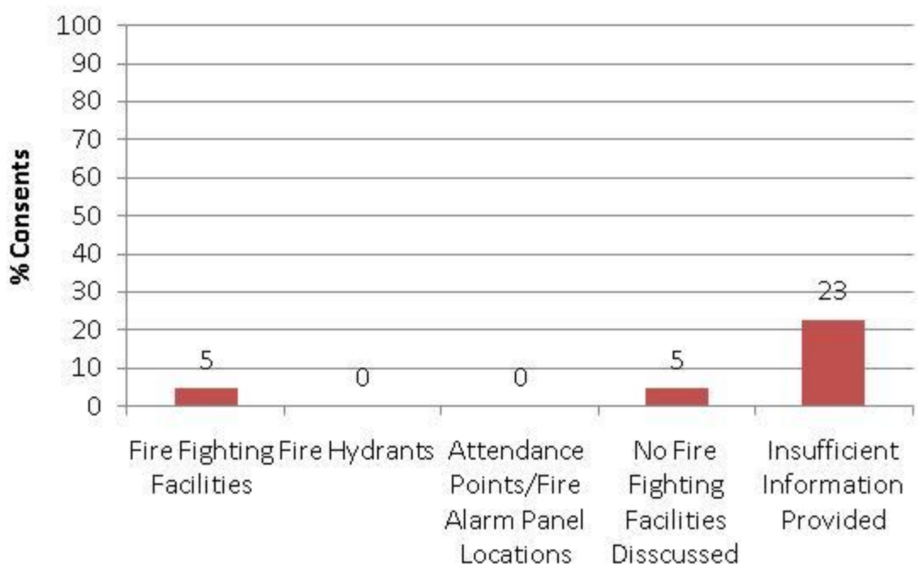

Figure 10 Fire-fighting facilities questioned within DRU memorandums for buildings undergoing alterations considered to be upgrades

Analysis of the DRU memorandums for buildings undergoing Alterations in accordance with s.112 (2) of the Act produced the following findings.

- Recommendations regarding fire-fighting facilities were provided in 5% of memorandums.
- The DRU did not raise any recommendations regarding internal fire hydrants.
- The DRU did not raise any recommendations regarding attendance points/fire alarm panel locations.

- In 5% of all submissions, no information at all regarding fire-fighting facilities were provided.
- Twenty-three percent contained advice stating that the documentation contained insufficient information to demonstrate compliance with the NZBC and recommended that further information be supplied.

3.4. Additional Findings impacting on Fire-fighting Response

3.4.1. Structural Fire Ratings

Recommendations regarding the adequacy or specification associated with structural fire ratings are shown in Figure 11.

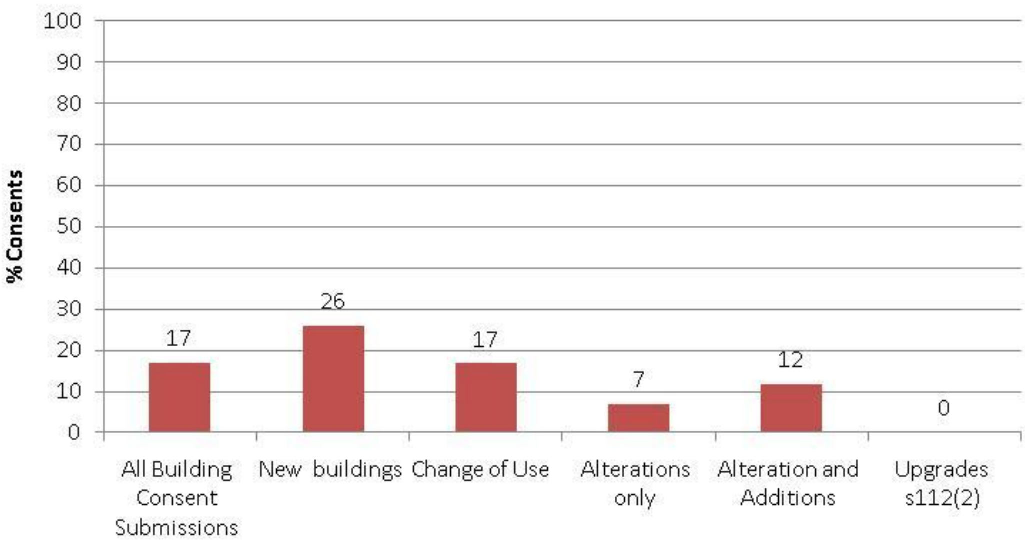

Figure 11 Recommendations regarding structural fire rating requirements

The findings indicate that within the DRU memorandums, recommendations were made regarding structural fire rating requirements as follows:

- all Building Consent submissions – 17%;
- new (proposed) buildings – 26%;
- existing buildings undergoing a Change of Use – 17%;
- existing buildings undergoing Alterations:
  - Alterations only – 7%;
  - Alteration and Additions – 12%;
  - Upgrades s.112(2) – 0%.

3.4.2. Computer Modelling

Computer fire models[3] are typically used to model fire development and as part of an egress analysis to demonstrate that occupants can safely egress from a fire compartment before the conditions within the compartment become life threatening. The robustness and quality of any design reliant on fire modelling to predict the fire environment can be affected by many factors. Those raised by the DRU with respect to the use and reliance on fire modelling typically include:

- the use of models outside of their validated limits;
- the use of unsubstantiated and unreferenced input parameters relevant to the subject building, such as design fire size, fire growth rate and combustion parameters etc.;
- the use of unsubstantiated and unreferenced tenability criteria.

Consent application using fire models to demonstrate compliance with the performance requirements of the NZBC accounted for 230 (21%) of the submissions reviewed as part of this review. The breakdowns by type of consent submission are shown in Figure 12.

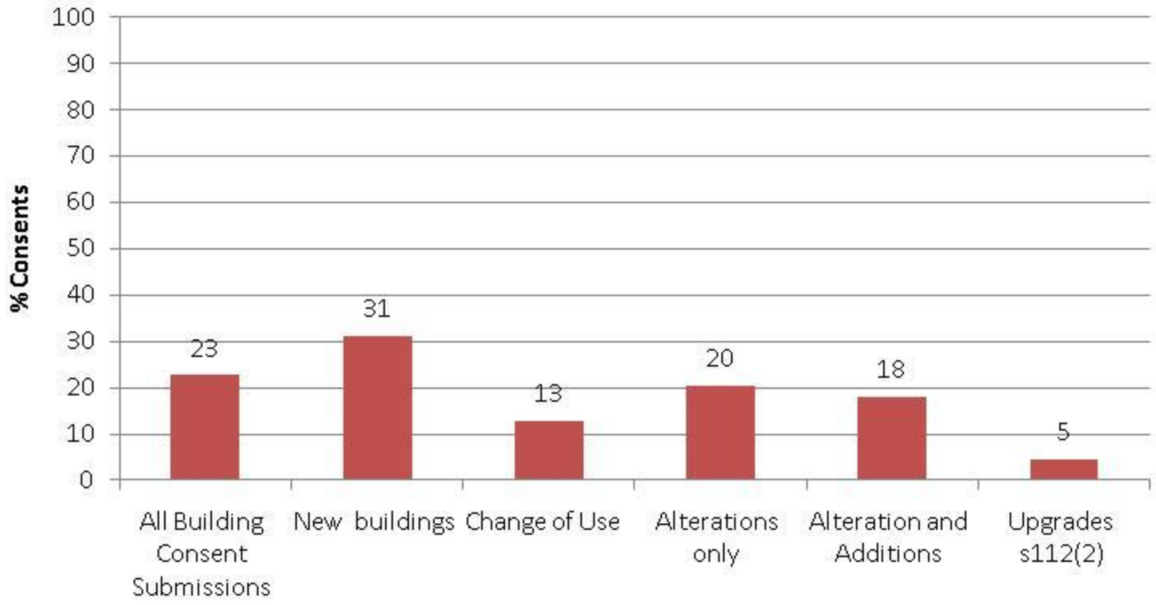

Figure 12 Building consent submissions using computer fire modelling

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[3] This definition does not include hand calculation methods or more advanced methods requiring the use of a computer spreadsheet, for example.

The breakdown by type of consent in which computer fire models were used is as follows:

- all Building Consent submissions – 23%;
- new (proposed) buildings – 31%;
- existing buildings undergoing a Change of Use – 13%;
- existing buildings undergoing an Alteration:
    - Alterations only – 20%;
    - Alteration and Additions – 18%;
    - Upgrades s.112(2) – 5%.

Figure 13 shows the percentage of consents containing fire modelling which were also provided with recommendations regarding the modelling.

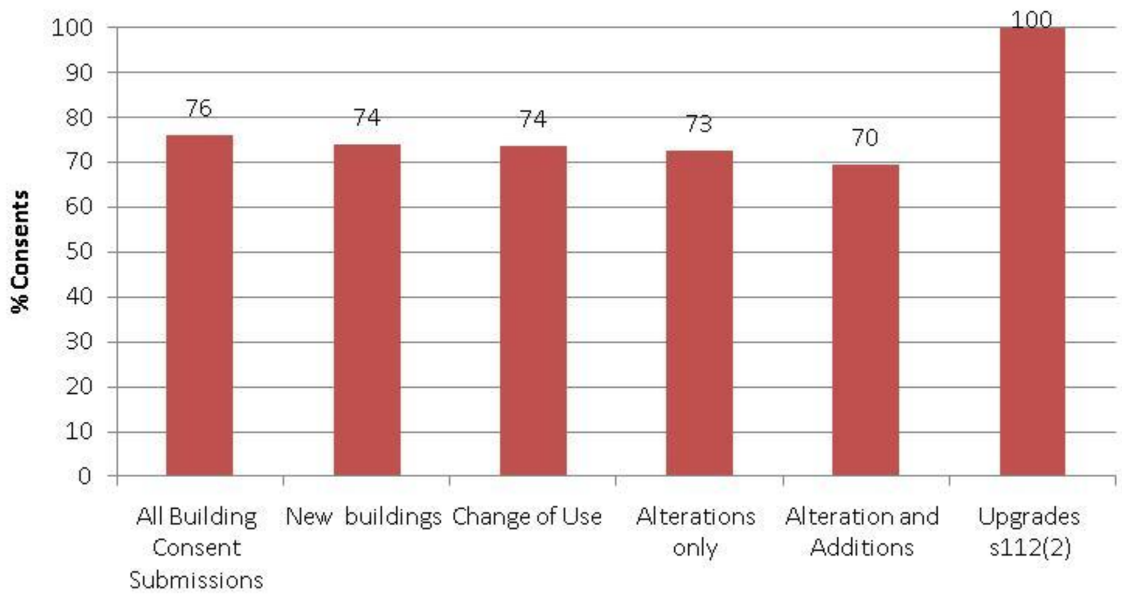


Figure 13 Percentage of recommendations made in submissions using computer fire modelling

The percentage of recommendations made within DRU memorandums regarding the use of fire models is as follows:

- All Building Consent submissions – 76%;
- New (proposed) buildings – 74%;
- Existing buildings undergoing a Change of Use – 74%;
- Existing buildings undergoing an Alteration:

- Alterations only – 73%;
- Alteration and Additions – 70%;
- Upgrades s.112(2) – 100%.[4]

Of the 230 building consent submissions reviewed that used computer fire models, the following findings present the breakdown of the different types of fire models used within the submissions.

- Zone models accounted for 158 or 69% of submissions with the following breakdown:
    - BRANZFIRE – 126 or 55%
    - CFAST – 20 or 9%
    - Firewind, Hot layer sub program – 12 or 5%.

- CFD models using only FDS accounted for 29 or 13% of submissions.
- Other models accounted for 60 or 26% of submissions with the following breakdown:
    - Firewind – 26 or 11%
    - Misc – 34 or 15%.

3.4.3. Management Procedures

The NZFS generally considers that there is an over-reliance on the use of management procedures and often sees the use of management procedures as compensating for the lack of provision of fire safety precautions required by C/AS1. An example would be the reliance on building staff to close fire doors rather than providing doors with the correct automatic closing mechanisms. The percentage of submissions reviewed for which the DRU provided recommendations with regards to the reliance on management procedures are shown in Figure 14.

[4] Only one submission presented a computer fire modelling to demonstrate compliance for an upgrade in accordance with s.112(2) of the Act.

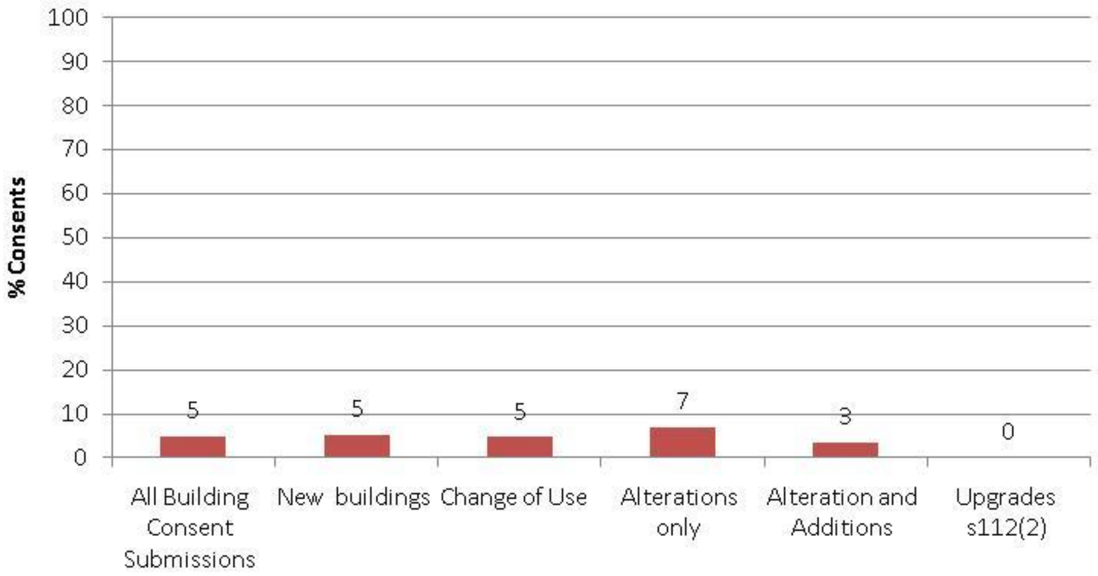


Figure 14 Recommendations made within DRU memorandums specific to management procedures

Recommendations regarding the use of management procedures were made in the following percentages of DRU memorandums:

- all Building Consent submissions – 5%;
- new (proposed) buildings – 5%;
- existing buildings undergoing a Change of Use – 5%;
- existing buildings undergoing an Alteration:
    - Alterations only – 7%;
    - Alteration and Additions – 3%;
    - Upgrades s.112(2) – 0%.

3.4.4. Water Supplies for Fire Fighting

The provision of water supplies for fire fighting is essential to ensuring the NZFS can undertake its legislative role adequately and safely. Building consent applications do not typically indicate if adequate[5] water for fire fighting is to be provided. Water supply provisions are regulated under the Resource Management Act and not the Building Act;

[5] 'Adequate' is considered to be that required by the code of practice for fire fighting water supplies PAS 4509.

thus, most fire reports consider that it is outside of the scope of a building consent application to consider water supplies for fire-fighting purposes. When the DRU began providing memorandums in 2005, recommendations regarding water supplies were provided. The recommendations ceased after the DRU was given specific advice from the DBH not to provide recommendations relating to water supply requirements. This issue is a concern for the NZFS as it is difficult to confirm if existing and new buildings are provided with sufficient water supplies to meet the needs of the NZFS without undertaking resource-intensive on-site testing after completion of the building. A critical part of the FBIM is to ensure that the water provisions on site are sufficient to meet the needs of the fire service given the size of the fire upon arrival and depending on the activities required of the fire service.

Whilst it is considered rare for building consent applications to address fire-fighting water supplies, an example of what is considered to be acceptable by some engineers in the industry follows. Within a recent Determination application dealing with the safety of fire fighters within a large cool store complex in excess of 5,000 m^2, the fire engineer asserted that approximately 4,000 litres (4 m^3) of water (the amount carried by the two NZFS appliances that would attend a fire in this particular location) would be deemed adequate to satisfy the requirements of the compliance documents and therefore the Act. This volume of water would not be sufficient to support any fire-fighting activities within a building of this size and construction. Of significant concern would be the implications of the NZFS not being able to source further water supplies at an incident at this building. In the event that fire-fighting activities requiring personnel to enter the building were required without sufficient water supplies being available, any personnel operating within the building would be at risk.

To rectify this problem, the DBH is considering placing additional performance requirements into the future version of the NZBC specifically dealing with fire-fighting water supplies (21). For the purposes of this research, it should be noted that an FBIM analysis would identify the water requirements required to support fire-fighting operations specific to the nature of the building being assessed.

3.4.5. Reports Sent to the DRU against the Advice of the Report Author

In accordance with s.46 of the Act, the type of building consent application that must be referred to the NZFSC is specified in the Gazette notice dated 24 March 2005. The Gazette notice has anecdotally confused many within the building industry and there is still debate as to which building consent applications are required to be sent to the NZFSC and which are not. The requirements of the Gazette notice are listed in Appendix A.

Commentary to this section of the Act provided by 'Brookers Online' states that:

> *In practice, that appears to mean that the only applications for building consent that need not be copied to the Fire Service are:*
>
> - *buildings designed to comply with the Acceptable Solution or verification methods for fire safety (C/AS1), emergency lighting (F6/AS1 or F6/VM1), and signs (F8/AS1);*
> - *single household units;*
> - *terraced or town houses;*
> - *sheds or other outbuildings; and*
> - *building work that has only a minor effect on a fire safety system. Such work would include the alteration of the tone or type of sounding or visual alert for a fire alarm but would not include work such as moving sprinkler heads.*

From this commentary, it is clear that almost all applications for building consent that involve an alternative solution or that deviate from the Compliance Documents should be sent to the DRU.

The confusion this causes has a number of implications with regards to the applications the DRU does and does not review under s.46 of the Act, and thus with respect to fire-fighting facilities. Whilst it is not possible to quantify the number of building consent applications that should have been sent to the DRU but were not, the NZFS Engineering Unit are aware of building consent applications that contained alternative solutions which should have been sent to the DRU. Ultimately it is up to the Building Consent Authority to decide which consents are submitted to the NZFSC for review; however, many take advice from and expect the fire engineering reports to identify the presence of alternative solutions and the need to refer the Consent documentation to the NZFSC.

Whilst it is not possible to quantify this problem, an increasing trend noted by DRU engineers is that certain authors of fire engineering reports specifically identify whether the report contains alternative solutions or not and whether the building consent application should be forwarded to the NZFSC for review. A total of 175 reports have been identified to date that have stated that the report should not be sent to the DRU for review. In total, 26 different fire engineering companies have been identified, of which three have authored more than ten fire reports that fall into this category. Of these three companies, two have produced 15 reports whilst one specific company accounts for 85 or 49% of these reports reviewed.

These results confirm that there is confusion over interpretation of the Gazette notice that can lead to misinterpretation of s.46 of the Act. It is also suggested that a number of building consent applications only containing minor non-compliances with the compliance documents are being sent to the NZFSC that may not strictly need to be sent for review under the Act. However, these findings also suggest that some companies, and one in particular, may be deliberately trying to avoid having fire reports sent to the NZFSC for review.

3.5. The Impact of Alternative Solutions and Building Performance in Fires

Whilst this research has identified significant issues associated with alternative designs and fire-fighting needs, it has not attempted to identify a link between the actual performance of these buildings in the event of fire. Hughes-Brown (22) investigated the link between alternative building solutions and real fires in the state of New South Wales (NSW), Australia and identified that the evacuation of occupants and fire service access were the principal areas of concern at real fires. A secondary concern identified from the fire investigations was the lack of adequate smoke management provisions in these buildings.

The report also identified a need to provide further studies on recording buildings with alternative solutions throughout NSW and Australia as well as a means to *"notify attending fire officers that there are alternative building solutions applied to the building which may contradict elements of their training and standard operating procedures".*

Even without investigating this issue in depth in New Zealand, the author believes this recommendation would also be relevant to the NZFS given the other issues identified in this section.

3.6. Conclusions

The findings contained in this chapter do not necessarily capture all recommendations made by the DRU that could have an effect upon fire-fighting facilities and the holistic effect of the proposed building designs upon fighting operations. It should also be recognised that DRU advice is provided in accordance with s.47 of the Building Act and as such does not constitute a peer review of all fire safety systems in the design. Other issues outside of the scope of the DRU assessment that could affect NZBC compliance and fire-fighting operations have not necessarily been captured within these statistics.

Whilst the recommendations provided within DRU memorandums may be taken up by the building consent authority and acted upon, there is no mandatory requirement to do so under the Act. There is also no requirement for the building consent authority to notify the NZFS if the recommendations have been considered. Therefore, it is not possible at the current time for the NZFS to quantify to what extent the issues identified by the DRU in this section impact on the ability of the NZFS to undertake fire-fighting operations.

Even with these limitations, the results of this statistical assessment clearly identify that there is a significant issue with respect to how the needs of the fire service are being addressed within fire engineering designs in New Zealand. Whilst many of the simple issues identified by the DRU need not require a full FBIM assessment to be undertaken, the most fundamental of FBIM assessments to understand the likely NZFS response times to the building would assist in demonstrating that the appropriate access requirements have been provided to meet the minimum requirements of the NZBC.

CHAPTER 4. Current Methods Used in New Zealand to Demonstrate Fire-fighting Needs

4.1. Introduction

This chapter provides information and discussion regarding the different methods currently used within New Zealand to demonstrate the performance requirements of the NZBC relating to fire brigade operations.

4.2. Holistic Design Process and Documentation

Chapter 3 identified concerns with respect to the provision of fire-fighting facilities given that for new buildings the NZFS DRU provided comment on fire-fighting facilities in 63% of building designs reviewed that used alternative fire engineering methods. However, it also needs to be recognised that in 67% of memorandums provided, the DRU stated that the documentation contained insufficient information to demonstrate compliance with the NZBC and recommended that further information be supplied. This indicates that concerns may not be exclusively related to the analysis methods chosen by designers, as insufficient information to demonstrate compliance may have been the reason why compliance could not be confirmed when being reviewed by the DRU.

This perceived lack of sufficient information and the provision of inadequate plans and specifications has been identified by a number of sources including the DBH in Determinations. A clear example includes Determination 2005/109 (23). In this particular determination relating to a single means of escape in a high-rise building, the DBH specifically concluded in section 14.2.4 that:

> *"Nevertheless, because of the lack of full plans and specifications, I would not have confirmed the territorial authority's decision to issue the building consent even if I had concluded that submissions justified the use of a single means of escape from fire."*

The 'Hot Topics' report (17) by the Institution of Professional Engineers New Zealand also identified that:

> *"The quality of engineering judgement and the supporting documentation is of variable quality, leading to a lack of confidence in the design solutions offered."*

Without appropriate supporting documentation and specifications detailing how the design will meet the needs of the NZFS amongst others, it is clear that any design will not demonstrate the performance requirements of the NZBC. Furthermore, without providing complete and final documentation, all of the factors that could have an impact on fire-fighting operations cannot be considered. Hot Topics also reported that authors of two technical audits of the DRU had provided commentary noting:

> *"the generally low standard of fire reports, lack of supporting calculations, inappropriate use or modification of the Acceptable Solution and over-reliance on unsubstantiated opinion purported to be expert judgement."*

One of these technical audits of the DRU (24) also identified (amongst others) the following finding:

> *Finding 8-1*
>
> *A review of the means of escape and firefighting provisions within a fire engineered design should not be conducted in isolation to other measures of the proposed strategy.*
>
> *Fire Engineering Design requires a holistic approach to an assessment; therefore, the review should also adopt this principle in associating aspects of a proposed fire engineering design to the provisions for the means of escape and firefighting. NZFS Design Review Unit should adopt this principle in discharging their duties in accordance with Section 47 of the Building Act 2004.*

This finding was further explained within the audit document with respect to DRU reviews. The audit said that when conducting an assessment of a fire engineering design, the DRU should analyse each aspect of it more holistically. That is, from the view point of how that aspect might impact on all other potential subsystems and aspects of the provisions for means of escape and fire fighting.

Overseas standards also recognise the importance of the holistic design process. BS 9999 (25) specifically warns against the need to assess fire engineering designs as a *'package of fire safety measures'* and that applying individual recommendations *'in isolation might give little or no benefit, and might even reduce the level of fire safety*' intended by the Standard.

From these findings, it is clear that appropriate documentation and a holistic approach to fire-fighting provisions is required to adequately demonstrate the performance requirements of the NZBC and specifically those relating to fire-fighting needs.

4.3. Building Consent Application Examples

The following examples are taken from building consent applications submitted to the DRU for review. These examples present a range of opinions expressed within building designs that directly affect NZFS operations and are provided to indicate how such facilities are viewed by engineers designing buildings.

4.3.1. Fire Hydrant Systems

Fire hydrant systems are necessary to ensure that fire fighters are provided with sufficient water inside buildings. Such systems are typical in high rise buildings and large facilities where fire fighters are required to operate at extended distances from fire appliances.

- *"The building does not have a fire hydrant system installed and therefore does not comply with the requirements of C/AS1. However, hydrant risers are primarily for the use of the New Zealand Fire Service to protect property. We believe it provides little benefit to the objectives of life safety during the early stages of the fire."*

- *"as the hydrant riser is utilized for Fire Service operations and not life safety for the occupants of the building it is our opinion that this precaution need not be provided…"*

- *“This is outside the scope of the of the Building Act requirements for means of escape, hence is not included in this design.”*

- *"A fire hydrant is required only for fire-fighting purposes and is unlikely to significantly increase the level of fire safety of the building occupants escaping from fire, and is therefore, in our opinion not required…"*

- *"'On behalf of our client, it is our proposal that a fire hydrant system is not necessary in this building on the following basis:*
    - *It would be impractical and expensive to install a hydrant system complying with NZS4510…in addition it is our view that as only one side of the building is accessible it is likely that the Fire Service would only be able to mount an external attack on any fire unless they were on site in the incipient stage of the fire growth, otherwise fire fighters entering the building could be at risk."*

The impact on fire-fighter safety and successful fire-fighting operations within a building that has not been provided with sufficient fire-fighting facilities such as internal hydrant systems should not be overestimated. The implications of deficient design can range from minor complications to severe restrictions in fire-fighting capability. It could mean additional efforts and time requirements to enable the set up and commencement of fire-fighting operations or the complete inability of a responding fire brigade to operate in the building presented due to equipment shortfalls or the premature reduction in compartment tenability conditions. An appropriate assessment either through FBIM analysis or by discussion with the appropriate fire authorities can establish what effects the lack of appropriate facilities may have on the responding fire brigade should a fire occur, and should establish what facilities are required to support fire-fighting operations within the building.

4.3.2. Structural Fire Ratings

Structural fire ratings are of significant concern to the NZFS as the requirement for structural fire protection extends beyond the egress of occupants from a building and needs to be sufficient to allow fire fighters to undertake their statutory function within the building. Any reduction in the prescribed structural fire rating requirements of the compliance documents needs careful consideration. However, for some building designs, especially those concerning industrial low-rise buildings, their fire designs can be basic in nature due to their layout. Such designs often suggest that the means of egress is straight forward and therefore that intervention from the NZFS, for either search and rescue or fire fighting requirements is not a requirement of the building owner and therefore for the design. In these designs it has not been uncommon to see the specified structural fire ratings either completely removed or significantly reduced from what would be otherwise required by C/AS1.

As discussed previously in section 2.7, Determination 2009/100 identified matters of doubt relating to the specification of substandard structural ratings provided to support an 18-storey building. Other structural fire rating examples include:

> This particular fire report acknowledged the locality and type of fire brigade that would respond to a fire in this proposed building as would be required within an FBIM analysis.
>
> *"New Zealand Fire Service resources in Kerikeri are volunteer staff, and the Kerikeri fire station is located approximately 8 Kilometres from this site. The Volunteers maintain a very professional and effective fire-fighting resource, and would be expected to respond to this site with two appliances within 13–16 minutes."*
>
> However, the fire report goes on to state, with respect to the structural adequacy of the building, that:
>
> *'an early collapse of the building in a timeframe of 10–15 minutes is anticipated'.*
>
> Given that the fire report also removed the automatic direct connection of the fire alarm system to the NZFS, there is no guarantee at what time during fire development arrival of the NZFS could be expected. However, even at best from the fire report comments, it is quite likely that arrival of the fire crews could be just prior to the onset of structural collapse of the building. Therefore, any crews attempting entry to the building at this stage would be at significant risk.

The functional requirement C2.2 (b) of the NZBC specifically requires that buildings shall be provided with means of escape from fire which give fire service personnel adequate time to undertake rescue operations. The above example provides a scenario in which the proposed building would not allow for fire fighters to undertake rescue operations should occupants not be able to escape from the building.

Further problems can also be seen when designers make assumptions regarding the ability of fire service personnel to be able to react to the environment given the building design. For example:

> *'In the opinion of the structural engineer, the loss of stability after the loss of the first roof brace will lead to observable movement in the structure warning responders to escape'.*

One would hope that such an observation would occur and that fire fighters would retreat from this situation. However, obvious questions need to be raised such as fire-fighters' ability to observe such movement in smoked logged compartments, and while undertaking either rescue or structural fire-fighting activities. The above example highlights a situation in which quantification of fire service activities along with the structural and fire assessment could have been undertaken to determine the conditions to which fire fighters would have been subjected and to assess whether the opinion expressed could have been validated by engineering analysis. The FBIM could have been used in this circumstance to support the required assessment.

For issues such as structural fire ratings that must consider fire brigade intervention it is difficult to see how deviations from C/AS1 or S ratings derived using alternative methods can be considered appropriate unless fire brigade intervention is considered. Without the use of a quantitative analysis tool such as the FBIM it is not possible to predict times of fire brigade operations or expected activities with any level of confidence and conclude that structural ratings are adequate. Consideration of fully developed post-flashover fires may prove conservative in this respect but where localised heating of structures may cause structural damage and potentially collapse, consideration specifically with respect to fire brigade intervention and the presence of fire fighters in and around the building should be made.

4.4. Performance-Based Designs

There have only been a few fire engineering designs submitted to the NZFS since 2004 that have been totally performance based, with little or no reference at all to the prescriptive requirements of C/AS1. The majority of building designs reviewed by the DRU consist of minor alterations from the Acceptable Solution and typically contain a limited analysis assessing only the deviation in isolation from any other requirement of C/AS1 of the performance requirements of the NZBC.

Performance-based designs for the purpose of this report are considered those which provide no reference to the compliance documents and only purport to demonstrate compliance with the Building Code by meeting the performance requirements of the Code using fire engineering methods. Although few designers actually attempt full performance-based designs, many of these to date have clearly demonstrated the issues identified in chapter 3, that the fire service is being ignored within building designs.

At the SFPE international conference on performance-based codes and fire safety design methods in April 2008, the lack of any accepted tool within New Zealand enabling fire brigade intervention to be assessed was specifically commented upon as a reason why fire brigade intervention was being ignored as part of building design. The following excerpt is taken from a New Zealand paper (26) presented at the conference and highlights this specific issue.

> *'3.1.2 Fire Service Life Safety*
>
> *The performance criteria for Fire Service safety require that conditions be maintained to facilitate Fire Service operations.*
>
> *There is currently no model for protection of Fire Service personnel during fire-fighting operations within the New Zealand legislation such as the Australian Fire Brigade Intervention Model (FBIM). The basis of the egress design will be that occupants are able to evacuate prior to their environment becoming untenable without requiring Fire Service intervention.* ***On this basis, Fire Service intervention will not be considered as part of this performance-based design.'***

Also with specific reference to fire brigade intervention, this proposed fire design did not use C/AS1 and was derived from first principles using performance-based design techniques.

> *'The acceptance criteria in the first instance is for life safety of the building occupants in the event of fire. Provided we meet the criteria above the fire services should be satisfied.'*

Other DRU findings taken from building consent applications include:

> *'The basis of the egress design will be that occupants are able to evacuate prior to their environment becoming untenable without requiring Fire Service intervention. On this basis, Fire Service intervention will not be considered as part of this performance-based design.'*
>
> *'We have only addressed the minimum requirements of the NZBC to achieve code compliance. As such, only the safety of building occupants has been addressed as required by the NZBC'.*

'There is no particular guidance in C/AS1 with regard to fire fighters and they are equipped with appropriate safety gear and in the business of fighting fires. Therefore the chosen criteria are to maintain the smoke level; at 1m above the floor for 10 minutes'.

There also appears to be a lack of understanding of the relationship between fire-fighting facilities and the function of the fire service to undertake rescue operations within fire-engineered designs. Facilitating the fire service to be able to undertake rescue operations is a mandatory requirement of the Building Act and Code. However, assuming that occupants will always be able to escape unaided and without the need of fire brigade intervention is typically assumed within designs, even when designers propose to remove or modify fire-fighting facilities.

4.5. Understanding of Fire Service Operations

It is apparent to the author that if buildings are to be designed that do not meet with the prescriptive requirements applicable to fire-fighting facilities then deviation from these requirements requires a fundamental understanding of fire service operations. Most fire engineering guidance documents recommend that designers liaise with the local fire services as a way of overcoming this issue. However, in New Zealand there is no mandatory way of enforcing such liaison and currently recommended engineering practice (17) such as the Fire Engineering Brief (FEB) process identified by the IFEG can be readily ignored by designers. Only when an understanding of fire service operations is known can designers appropriately plan facilities for fire service operations taking into account variations that may be unique to a specific building and responding fire service. There is an apparent lack of knowledge from designers regarding fire service operations let alone local variances that may exist. This can be seen when reviewing the design reports for buildings in which fire service operational issues have been altered. The following quotes are again taken directly from fire reports submitted for building consent applications:

General:

- *'No fire systems centre is provided. It is considered not reasonably practicable to install a new fire systems centre given that it is for supporting fire-fighting operations and does not provide any level of protection to occupants' safety.'*

- *'Fire Service lift control is not currently provided. We believe this feature provides little benefit to the objectives of life safety during the early stages of the fire and as such is not required…'*

- *'The Fire Service's preferred method of communications is via newer and more technologically advanced RT systems or cellphones in the unlikely event that this fails'.*

4.6. Fire-fighting Water Supplies

As discussed in section 3.4.4, most fire reports consider that it is outside of the scope of a building consent application to consider water supplies for fire-fighting purposes. However, there have been a number of designs produced where fire-fighting water supplies have been identified as relevant to the building design. The example provided in section 3.4.4 identified how a lack of understanding of fire-fighting operations and needs of the fire service has effectively precluded fire-fighting operations within that building. In reality however, fire fighters may be put in a position where they enter the building and place themselves and others at a greater risk than would have otherwise been present, if sufficient water supplies had been made available on site.

4.7. Assessment of Building Consent Applications

It should be acknowledged that interpretation of the information provided thus far needs further explanation with regards to how designers go about presenting information within fire engineering designs. One of the main changes to the Building Act 2004 was the requirement for consent applications to clearly demonstrate how the requirements of the Building Code are to be achieved. It is still apparent, especially with regards to fire-fighting facilities, that many designers still consider that these issues can be resolved after the consent process has finished. Examples include:

- *'However, it should be confirmed that a suitable hydrant is available for fire-fighting water supplies and is within the prescribed distances for NZ Fire Service use'.*

- *'Discuss fire engine access with Fire Service, particularly axle loads on pavements.'*

- *‘No requirement for type 18 fire hydrant system provided that Fire Service hose run does not exceed 75m.’*

The issue with these types of statements is that the building design stage has passed and it becomes difficult, if not impossible to change the building to accommodate any additional requirements not already included within the design. This is especially true when features might require physical building space in which to be located. Unfortunately, as a result it is not uncommon for such designs to be accepted by Building Consent Authorities and consent granted by which time such issues are overlooked until it is too late. The result is that these fire service features are either ignored or are compromised as a result.

The leaky building crisis was brought about because of similar issues, which should not occur. This is made clear within the book “Deconstructing the Building Act” by the Department of Building & Housing senior legal advisor, Brian Cashin (27) which states:

- *“The submitted plans and specifications must include everything the builder (including subcontractors) needs to know to complete the building…It is no longer acceptable to include a fire engineer’s report of what should be done, for example wall A7-Y9 to have a 4 hour FRR, the plans and specification must show how this is to achieve the fire resistance rating ”.*

Another significant problem from an NZFS perspective is that rarely are consent applications resubmitted to the DRU to confirm if any changes have been made following the DRU memorandum. If consent applications were to be resubmitted to the NZFS, as they should be according to Cashin, it is likely that the NZFS would have a greater confidence in the building consent process and that many of the concerns presented above would be resolved.

4.8. Lack of Reference Design and Prescriptive Criteria

One definite advantage that Australia has over New Zealand with regards to the use of the FBIM is the presence of a ‘reference design’ or the ability to undertake the analysis based on a comparative compliant or ‘deemed to satisfy’ design. The Building Code of Australia (BCA) has the ‘deemed to satisfy’ prescriptive solutions to which any alternative is required to demonstrate a comparative level of safety. Use of the FBIM in Australia can be compared to a prescriptive solution and thus the implications of any proposed alternative can be readily compared. In New Zealand however, C/AS1 references the use of '*specific fire engineering design'* throughout the document. Although seen by many as an indication of how advanced the C/AS1 document is, this has had a significant effect upon how fire engineering has evolved within New Zealand as there has been no specific definition of what this term means or requires. With regards to fire brigade intervention, there are numerous references to '*specific fire engineering design'* throughout the document. The most obvious reference to fire service operations that requires '*specific fire engineering design'* is that of large Fire Hazard Category 4 buildings. Some of these issues have been addressed above and have evolved to the situation where it is now commonly accepted for designers to ignore fire brigade intervention as part of '*specific fire engineering design'.*

This specific issue was identified within the NZFS Inquiry following the explosion and fire at the Icepack Cool stores, Tamahere (28). In that report, it specifically stated that:

> *'None of the fire reports assessed the building's risk through specific fire engineering design methods.'*

4.9. Conclusions

This chapter has identified that some building design methods currently used within New Zealand are considered to be inappropriate and inadequate to demonstrate or justify an alternative solution in many aspects of compliance that affect fire-fighting needs. This fact highlights a number of issues including the need for better communication between the design engineer and NZFS. This research has also identified the current belief that the lack of any available engineering analysis tools to quantify and establish fire brigade intervention activities is being used as an excuse to ignore this crucial aspect of any fire engineering design. The promotion of the FBIM through this research project and by the collection and validation of New Zealand data should rectify some of these concerns.

It is also considered by the author that 'performance requirements' have no place being present within a prescriptive compliance document. Until the Acceptable Solution C/AS1 is amended to remove all references to '*specific fire engineering design',* there will be no benchmark and no lower limit defining an accepted level of safety to the fire service within many types of buildings. Without an accepted level of safety or the minimum expectations defined it is considered that there will always be problems with the analysis of fire-fighter needs and the application of the FBIM within the New Zealand context.

CHAPTER 5. Fire-fighting Requirements within Other International Performance-Based Building Codes.

5.1. Introduction

Performance-based designs and the application of fire safety engineering vary around the world dependent on regulations specific to each location. However, the general principles that must be applied to fire engineering should be relatively consistent irrespective of local regulations, given that the objectives of life safety are global. This chapter provides relevant information pertaining to regulations and guidance documents produced outside of New Zealand specifically relating to the consideration of fire-fighting needs. This allows a comparison to be made with the regulations and guidance documents currently available and used in New Zealand and provides an opportunity to identify if there is a need to update requirements and the guidance documents commonly used in New Zealand.

It is first necessary to understand what constitutes fire safety engineering. The international standard for fire safety engineering (29) defines fire safety engineering as:

> *the application of engineering principles, rules and expert judgement based on a scientific appreciation of the fire phenomena, of the effects of fire, and of the reaction and behaviour of people, in order to:*
>
> - *save life, protect property and preserve the environment and heritage;*
> - *quantify the hazards and risk of fire and its effects;*
> - *evaluate analytically the optimum protective and preventative measures necessary to limit, within prescribed levels, the consequences of fire.*

This chapter does not intend to identify all the countries that currently have performance-based codes in place. Proceedings such as those from the SFPE International Conference on Performance-Based Codes and Fire Safety Design Methods typically contain many papers addressing the codes specific to individual countries. This chapter does, however, make reference to and provide discussion on those codes, regulations and methods available internationally that are relevant to the FBIM and the situation within New Zealand.

5.2. International Guidance

5.2.1. ISO/TR 13387-1:1999

Annex F of the international standard for Fire Safety Engineering (29) contains an informative section specifically dealing with fire-fighting and rescue facilities. This recognises that sufficient consideration must be given to the interaction of fire services for fire-fighting intervention purposes. It also stresses that an analysis in liaison with the fire service should be undertaken but recognises that fire fighting and rescue operations are extremely difficult to quantify. The standard does not propose any methodology to assist designers with quantifying fire-fighting operations but gives the following factors that need to be taken into account within the assessment:

a) *whether the firefighters are full-time or volunteers;*
b) *the availability of specialist appliances and equipment;*
c) *the precise nature and location of the fire incident;*
d) *the position and condition of persons requiring assistance during the evacuation (or rescue if the life safety design system has failed).*

The standard then goes on to state:

> *The design of the building, and the facilities provided, can now be reviewed to ensure that:*

a) *there is sufficient means of external access to enable fire appliances to be brought near to the building for effective use;*
b) *there is sufficient means of access into, and within, the building for firefighters to assist in the evacuation, to effect rescue (where necessary) and to fight the fire;*
c) *the building is provided with sufficient fire mains and other facilities to assist firefighters in their tasks;*
d) *the building is provided with adequate means of venting heat and smoke from basement areas.*

5.2.2. ISO Technical Report 16738

The introduction to the ISO technical report 16738 on methods for evaluating the behaviour and movement of people (30) recognises that occupants' response to a fire is influenced by fire brigade intervention. This report states (emphasis added):

> *The response of occupants to a fire condition is influenced by a whole range of variables in these four categories, related to the characterization of the occupants in terms of their number, distribution within the building at different times, their familiarity with the building, their abilities, behaviours and other attributes; the characterization of the building, including its use, layout and services; the provision for warnings, means of escape and emergency management strategy; and the interaction of all these features with the developing fire scenario and* ***provisions for emergency intervention (fire service and rescue facilities).***

Although outside the scope of this report, section C5 of ISO 16738 also recognises that the safety of occupants can be reliant on fire brigade intervention:

> *Circumstances can arise in a building where the intervention of the fire service is necessary to secure the safety of the occupants. To assist the fire service in the execution of intervention strategies,* ***it is necessary to include appropriate facilities in the design of the building.***

5.2.3. International Fire Engineering Guidelines

The International Fire Engineering Guidelines (14) is an important guidance document because of its adoption and promotion in New Zealand as previously discussed in section 2.6. The IFEG are unique as although they were primarily developed for use in Australia, they were updated in 2005 through a collaboration of bodies including the Inter-jurisdictional Regulatory Collaboration Council (IRCC), the Australian Building Codes Board (ABCB), the National Research Council of Canada (NRC), the International Code Council (ICC) of the United States of America and the DBH. These guidelines are now considered to be truly international and are relevant for use within Australia, Canada, United States of America and New Zealand.

Sub-system F (SS-F) is specific to fire-fighting needs and provides, amongst other things, guidance on quantifying times for:

- the arrival of the fire services at the fire scene;
- investigation by the fire services;
- fire services set-up;
- search and rescue;
- fire services attack;
- fire control;
- fire extinguishment.

The IFEG acknowledges that in many fire engineering designs the effect of fire brigade intervention on the fire is not taken into account. However, the IFEG stresses that:

- *"This, however, does not mean that the fire engineering evaluation should discount the needs of Fire Services carrying out their intervention activities."*

Chapter 2.9.1 of the IFEG references the use of the FBIM to quantify fire service activities to allow the design to incorporate fire brigade intervention. It then follows that the FBIM should be an accepted tool to demonstrate the performance requirements of the NZBC as it is referenced by publications endorsed by both the DBH and IPENZ.

5.2.4. International Code Council Performance Code

The ICC publish a 'Performance Code for Building and Facilities' (ICCPC) (31) and also the International Fire Code (32) which are available and can be adopted internationally; however, their membership appears to be largely based in the United States of America.

Part 3 of the code deals with fire and there are specific requirements placed on fire-fighting intervention requirements throughout the document. Section 103.3.4.1.6 provides requirements for design documentation and those specific to emergency response capabilities. Of relevance is that this requires the documentation to clearly describe the *'level of response expected by emergency responders under the direct control of the owner*', as well as capability of emergency responders. Chapter 602.2.2 sets out functional statements of the code relating to fire-fighters' needs. Similar to those in the NZBC this requires that *'buildings and facilities shall be designed and constructed so that fire fighters can appropriately perform rescue operations, protect property, and utilize fire-fighting equipment and controls*.'

There is also a dedicated section 2101.3, specific to protecting emergency responders from unreasonable risks during emergencies. The performance requirements set out in this section specifically include the identification of hazards, appropriate signage, ensuring that collapse, if it occurs, is predictable and the provision of communication systems in certain buildings.

Additionally, the ICCPC provides a *'User's Guide'* to the Code which describes the rationale and basis for the performance requirements. The guide acknowledges that fire fighting is an inherently dangerous activity but provides provision to alleviate the hazards that are considered to be beyond those normally expected by fire fighters during an emergency. Such guidance is lacking in New Zealand and forces designers and engineers to make interpretations of the performance requirements of the NZBC resulting in the findings presented in chapter 1. Chapter 21 of the User's Guide is again specific to emergency responder safety.

5.3. Australia

As the FBIM is specific to the Australian and New Zealand fire engineering environment, chapter 6 of this report provides specific information relating to the use of the FBIM in Australia and how its use is affected by the regulatory environment found in the different Australian states. This section is provided only to identify the aspects of the Building Code of Australia that specifically relate to fire service intervention.

5.3.1. Building Code of Australia

Following New Zealand, Australia also introduced a performance-based building code (33) in 1996 with a similar structure, the only significant difference being the incorporation of the additional layer defining compliance with the performance requirements:

(a) The Objectives.

(b) The Functional Statements.

(c) The Performance Requirements with which all Building Solutions must comply.

(d) The Building Solutions.

A Building Solution in the BCA is defined as a solution which complies with the Performance Requirements and is:

(a) an Alternative Solution; or

(b) a solution which complies with the Deemed-to-Satisfy Provisions; or

(c) a combination of (a) and (b).

As in New Zealand, the ABCB publishes a set of solutions similar to C/AS1 which are termed the '*Deemed-to-Satisfy Provisions'.* Of significant difference in the BCA compared with the NZBC is that the Guide to the BCA (34) specifically states that to meet the performance requirements of the BCA an alternative solution must be shown to be at least equivalent to the '*Deemed-to-Satisfy Provisions'*. No such statement exists within the NZBC, which is important when considering the substitution or removal of fire safety systems that impact on fire brigade intervention.

A0.5 Meeting the Performance Requirements

Compliance with the Performance Requirements can only be achieved by—

(a) complying with the Deemed-to-Satisfy Provisions; or
(b) formulating an Alternative Solution which—
(i) complies with the Performance Requirements; or
(ii) is shown to be at least equivalent to the Deemed-to-Satisfy Provisions; or
(c) a combination of (a) and (b).

Other than fire safety systems and other relevant terms, the BCA contains specific reference throughout to fire brigade intervention which makes the FBIM directly applicable as can be seen below:

SECTION C FIRE RESISTANCE

PERFORMANCE REQUIREMENTS

CP1

A building must have elements, which will, to the degree necessary, maintain structural stability during a fire appropriate to—

(i) ***fire service* intervention**; and

CP2

(b) Avoidance of the spread of fire referred to in (a) must be appropriate to—

(ix) ***fire service* intervention**; and

CP9

Access must be provided to and around a building, to the degree necessary, for *fire service* vehicles and personnel to facilitate ***fire service* intervention** appropriate to—

(a) the function or use of the building; and

(b) the *fire load*; and

(c) the potential *fire intensity*; and

(d) the *fire hazard*; and

(e) any active *fire safety systems* installed in the building; and

(f) the size of any *fire compartment*.

SECTION D ACCESS AND EGRESS

DP5

To protect evacuating occupants from a fire in the building *exits* must be fire-isolated, to the degree necessary, appropriate to—

(e) ***fire service* intervention**.

PART E1 FIRE-FIGHTING EQUIPMENT

EP1.6

> Suitable facilities must be provided to the degree necessary in a building to co-ordinate ***fire service*** **intervention** during an emergency appropriate to—
>
> (a) the function or use of the building; and
>
> (b) the *floor area* of the building; and
>
> (c) the height of the building.

During development of the BCA, AFAC were involved ensuring that the needs of the fire services were effectively incorporated into the code. However, this was a two-way process and it is understood that the ABCB considered that it would not be possible to develop a robust performance-based code that incorporated the needs of the fire services unless an appropriate tool could be developed. Such a tool would have to be developed on a performance basis so that it could be used in conjunction with other recognised engineering methods. Out of this need came the production of the FBIM and hence the expectation that the FBIM would be used to meet the performance requirements of the BCA.

To support performance-based fire engineering, the ABCB published the Fire Safety Engineering Guidelines in 2001 which later became the IFEG (14). As a result, the IFEG process and methodology is practically mandated and enforced for any alternative solutions proposed within Australia. Of significance is that both the IFEG and FBIM are specifically mentioned within the Guide to the BCA as example reference documents that could be used when undertaking Alternative Solutions (34). Section A0.8 of the Guide has been reproduced in Appendix B for specific reference.

5.4. United Kingdom

England and Wales adopted one of the earliest performance-based building codes for fire in 1985 (35). Similar to New Zealand, the UK Building Act 1984 is the primary legislation under which the Building Regulations are enforced. This is applicable to England and Wales but not to Scotland or Ireland. For building work, the UK Building Regulations specify technical requirements which are required to be met. Guidance on meeting these technical requirements is provided in the form of 'approved documents'. Approved Document B (36) is one of 14 such documents and is specific to fire safety.

In 2006 The Regulatory Reform (Fire Safety) Order 2005 came into effect and replaced over 70 pieces of fire safety law (37) throughout the UK. The 2005 order applies to all non-domestic premises in England and Wales and had a significant effect on how fire safety is managed in the UK, with a strong influence on fire safety risk assessment. From a design perspective, a comprehensive range of guidance documents and standards are available dependent on the nature of the building being designed, the method of design and the complexity of the project. BS 9999 (25) provides a three-tiered hierarchy to define the approaches and methods that should be used for fire engineering in the UK:

> *a)* ***General approach****. This level is applicable to a majority of building work undertaken within the UK. In this case the fire precautions designed into the building usually follow the guidance contained in the documents published by the relevant government departments to support legislative requirements.*

> *b)* ***Advanced approach****. This is the level for which BS 9999 is provided. Guidance provided in this document gives a more transparent and flexible approach to fire safety design through use of a structured approach to risk-based design where designers can take account of varying physical and human factors. Much of the guidance in BS 9999 is based on fire safety engineering principles, although it is not intended as a guide to fire safety engineering.*

> *c)* ***Fire safety engineering****. This is the level for which BS 7974 is provided. This level provides an alternative approach to fire safety and can be the only practical way to achieve a satisfactory standard of fire safety in some large and complex buildings, and in buildings containing different uses.*

Documentation supporting all three approaches contains specific advice and details of how to satisfy the performance requirements for fire-fighting needs of the Building Code. The following sections provide relevant observations from each of the three documents supporting these different approaches.

5.4.1. General Approach – Approved Document B

Section B5 of Approved Document B (36) provides the requirements for access and facilities for the fire and rescue services. Of specific note is that the document acknowledges the impact of fire-fighting intervention on means of escape strategies from some large buildings. Section 4.27 recognises that fire fighters entering stairs may impede evacuating occupants and recommends that for buildings in excess of 30 m in height special management procedures be put into place in consultation with the relevant fire and rescue service. However, for buildings in excess of 45 m physical measures may be required, and discounting a stair is suggested. The recommendation for an additional stair should also be recognised to be in addition to other dedicated measures such as vertical shafts or fire-fighting shafts specifically designed for fire-fighters' use.

5.4.2. Advanced Approach – BS 9999

Section 6 of BS 9999 (25) is dedicated to the requirements surrounding access and facilities for fire fighting. Both Approved Document B and BS 9999 require far more comprehensive fire-fighting facilities than New Zealand's equivalent, C/AS1. Of interest in section 20 of BS 9999 is that the introduction recognises that facilities should be provided to assist fire fighters in undertaking more than just rescue operations. Also, the need to ensure that fire fighters are provided with places of relative safety within buildings is relevant to understanding the needs of fire fighters while operating within buildings. Text from section 20 of BS 9999 is provided below with emphasis added to these points:

> *Fire-fighting facilities should be selected and designed to assist the fire and rescue service in protecting life, protecting fire-fighters,* ***reducing building losses, salvaging property and goods and minimizing environmental damage.*** *Early consultation with appropriate approving authorities (including the fire and rescue service and building control bodies) is recommended when deciding which facilities should be provided. Fire-fighting facilities should include, where appropriate:*
>
> *a) the provision of vehicular access for fire appliances to the perimeter of the building or site;*
>
> *b) provision of easy and speedy entry to the site and/or the interior of the building for fire-fighters and their equipment;*

c) provision of and access to sufficient supplies of a fire-fighting medium;

d) means of enabling fire-fighters, once they have entered a building, to reach any point within that building in the shortest possible time, including the provision of fire-fighting lifts if appropriate;

e) means of ensuring that once fire-fighters have arrived at a location within a building, they can remain there in relative safety whilst they carry out their fire-fighting operations;

f) provision for fire and rescue service communications;

g) provision of facilities to release, or extract, smoke and heat from the building or site;

h) provision for removing spent fire-fighting extinguishing medium.

5.4.3. BS 7974 – Fire Safety Engineering

The published document PD 7974 Part 5 (4) is specific to 'fire service intervention' and is provided to support the code of practice, BS 7974:2001, Application of fire safety engineering principles to the design of buildings(38). This is a directly relevant document to the consideration of fire brigade intervention and the FBIM. Section 4 provides the general guidance for any analysis and specifically notes that:

Consideration needs to be given regarding physiology data of fire-fighters, heat stress, training, fire-fighting techniques, breathing apparatus constraints etc.

Of particular relevance is that the document provides no accepted engineering method to establish intervention times, as it states that this is difficult to quantify and provides only qualitative times based on judgement;

fire service activities are not easy to quantify. Many aspects of this Published Document have to be based on qualitative judgement rather than on numerical calculations.

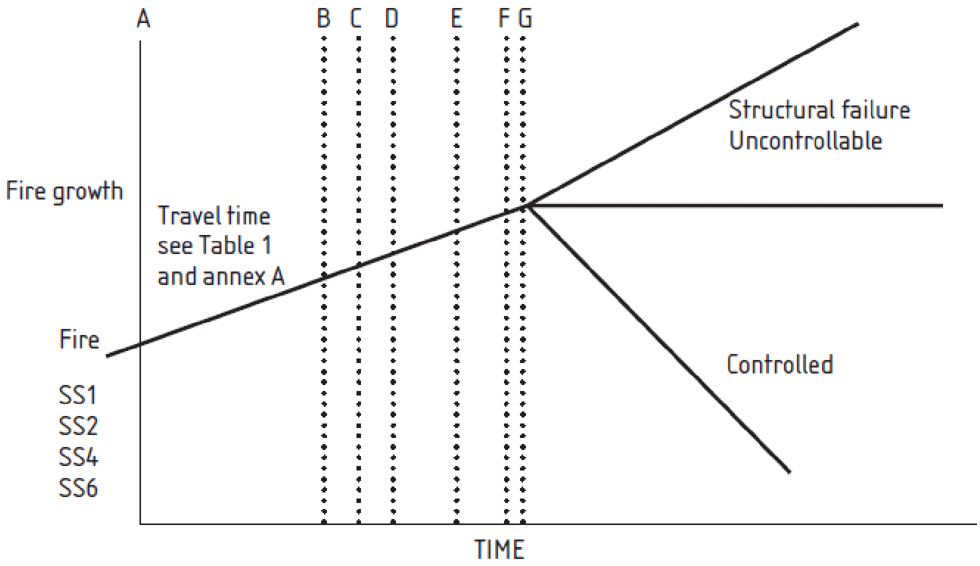
Section 5 provides the inputs required for the analysis which include:

- Building characteristics
  - Building layout and geometry
  - Building location
  - Access to the building
  - fire service facilities
- Physiology of fire-fighters
- Design fire
- Time of fire service notification
- Evacuation time
- Environmental influences on smoke control
- Vehicle access
- Water supplies
- Single-storey and multi-storey complexes
- Fire-fighting shafts
- Fire-fighting stairs, lobbies and lifts

The outputs for the analysis required are given as:

- Time of fire service intervention
- Fire service extinguishing capability

The similarities between PD7974 and that of the FBIM can be seen diagrammatically in Figure 15, which shows the results of a PD7974 analysis of fire service intervention.



KEY
A Time of call to fire service
B Arrival time
C Assessment and planning
D Assembling fire-fighting resources
E Travel within building from the point of access to the fire-fighting bridgehead
NOTE 1 This may include horizontal and vertical travel and 7.3 should be considered.
NOTE 2 The speed and size of fire-fighting lifts can have an impact on travel time.
F Setting up the fire-fighting bridgehead (including the provision of a reliable water supply)
G Commencing fire-fighting operations

Figure 3 — Fire service intervention

Figure 15 The defined stages of 'Fire service intervention' taken from PD7974-5

The similarities between PD7974 and the FBIM as a way of quantifying fire-fighting needs on a performance basis could be considered to provide a level of validity to FBIM and the respective methodologies and also suggests that they are sound and transferable between countries and across codes. However, the weakness with PD7974 is that it lacks credibility from an engineering sense as the values or data required for any analysis are too generic and not building-specific and are largely qualitative in nature. This is problematic from a true performance perspective as generic qualitative data will ultimately produce a generic prescriptive result. The obvious example of this is that the arrival time of the fire service is predicated on government recommended national standards of fire cover rather than actual resourcing and response times associated with buildings in specific areas and serviced by a local fire service with specific characteristics. This is further discussed below in section 7.5.2 Historical Background to Fire Service Response Times.

5.5. United States of America

The Building Construction and Safety Code, NFPA 5000 (39), allows performance-based designs providing they meet with the goals and objectives set, including *'reasonable safety for fire fighters and emergency responders during search and rescue operations'*. The code also requires that, as well as means of egress, the building or structure be provided with other fire and life safety safeguards relevant to eight listed factors, one of which includes the *'capabilities of response personnel'*.

Chapter 5 sets out the performance criteria that the design must meet to achieve the goals and objectives of the code. Three of these performance criteria are specific to fire-fighting needs and are directly relevant to the FBIM. They are given below with emphasis on the reference to time components:

> *5.2.2.5* Buildings shall be designed and constructed to reasonably prevent structural failure under fire conditions* ***for a time sufficient to enable fire fighters and emergency responders to conduct search and rescue operations****.*
>
> *5.2.2.6* Buildings shall be designed and constructed to reasonably prevent fire spread to adjacent buildings and structures* ***for a time sufficient for emergency responders to arrive on-site and establish fire suppression operations****.*
>
> *5.2.2.7 Access shall be provided to enable fire apparatus to reach the principal building entrance for fire department use and to reach the fire emergency equipment provided for the building.*

Paragraph 5.4 provides the characteristics and assumptions to be used for emergency response personnel. As with all the performance-based design methods discussed within this document, this paragraph also states that no reliance should be placed on the emergency responders as part of the design. However, an exception to this is provided in situations where the emergency responders are under the direct control of the building owner or occupant. Of specific note from an FBIM design perspective, paragraph 5.4.4.2 is the requirement to document the design characteristics and assumptions related to the emergency responders:

5.4.4.2 Design characteristics and assumptions related to the availability, speed of response, effectiveness, roles, and other characteristics of emergency response personnel shall be specified, estimated, or characterized sufficiently for evaluation of the design.

NFPA 5000 provides a performance-based approach stating the performance requirements which need to be met to achieve the goals and objectives for an appropriate design. Criteria specific to fire fighting is provided with the expectations set out as to what characteristics and information is required to achieve these specific performance requirements. However, the code does not provide or reference any acceptable quantitative methods of how to achieve these criteria or how to demonstrate that the performance requirements specific to fire fighting can be shown to be 'sufficient'. It is unclear therefore to the author how such performance criteria are expected to be justified and without such guidance it would appear that such decisions would come down to the individual circumstance and requirements of the authority responsible for approval of the design.

5.6. Canada

The FBIM Manual (5) discusses the Fire Risk Evaluation and Cost Assessment Model (FiRECAM) (40) which is used in Canada and specifically the shortfalls perceived with the model at that time. There is no intention to address the model in any particular detail here except to note that FiRECAM is intended to assess the level of fire safety that is provided to the occupants in an apartment or office building. It is also claimed that by comparing the proposed building with a code compliant design, the model can assess whether a proposed design meets the performance requirements and is equivalent or better from a performance-based life-risk perspective. At the time of writing, the FiRECAM model was under development and not available for comparison with that of the FBIM computer program. However, the similarities between FiRECAM and the FBIM can be readily observed.

Also under development in Canada is the Fire Evaluation and Risk Assessment system (FIERAsystem) which is similar to FiRECAM but with a current focus on aircraft hangars and warehouses. FIERAsystem contains two sub-models including the Fire Department Response Model (FDRM) and the Fire Department Effectiveness Model (FDEM) which can be used as stand-alone models (41). Of relevance to the FBIM is that the timing of fire service intervention is calculated by the FDRM and is used in the calculations of the FDEM in a very similar fashion to that of the FBIM.

Bénichou et al (41) presents a number of 'typical' values such as that of 5- to 6-minute response times for fire departments and a preparation time of 1 minute. Bénichou et al also state that the model has been designed to accommodate the future research and data required to populate the model which will be required to accurately predict the time associated with responses from local brigades. For the FDEM model, output calculations including the total heat release rate without fire department intervention, the total heat release rate after fire department intervention as well as the revised fire's properties after fire department intervention are provided. There are no goals or objectives set as part of the models discussed and only values given for typical fire service responses. It is not therefore apparent how such a model can be used and evaluated against the performance requirement of the Canadian Building Code. A case study (42) identified how FiRECAM could be applied to a 40-storey office building and includes identification of fire brigade intervention and the effect of the proposed design. However, this case study is based on a comparative analysis of a code compliant building and assumes that a prescriptive design case is in place to be assessed against. Whilst such comparative assessment methods are increasingly becoming more accepted worldwide as in New Zealand, this method first requires a comparison building design to be available based on the prescriptive requirements. As identified in chapter 1, with New Zealand's Acceptable Solution C/AS1 being so limited in scope and application, this comparative design approach is not always available.

5.7. Finland and Iceland

Tillander (43) and Tomasson et al (44; 45) identified the need to incorporate all of the influences and effects that comprised the overall risk in a high-rise building design and that the time associated with fire brigade intervention needs to be incorporated into the risk assessment model. Quantitative Risk Analysis (QRA) methods including Monte Carlo analysis to support probabilistic assessment for fire brigade intervention times are proposed. These papers identified that for buildings such as high-rise buildings, the consequences associated with building systems failures and fire brigade intervention times becomes more critical than for conventional buildings. The result identifies the efficiency of various fire safety systems and identifies at which point in time fire brigade intervention could become unsuccessful based on predicted heat release rate, given the building design. The reported conclusions indicate that the simulated response times of the fire service can be used to assess the influence that fire service activities have on the overall safety of the building and that by using such a model from a performance-based perspective it can provide a transparent and accepted method to demonstrate code requirements.

CHAPTER 6. The Use of the Fire Brigade Intervention Model in Australia

6.1. Introduction

Whilst the NZFS was involved with the development of the FBIM, it is not in regular use in New Zealand and few engineers have an in-depth or practical knowledge of its use for design purposes. Therefore, to understand how the FBIM is used and perceived in Australia where the model is used on a more regular basis, a research trip was undertaken to Australia. This chapter provides the results of this research and is intended to provide information on the use of the FBIM in Australia and therefore how it should be or might be best applied in New Zealand.

6.2. Australian Research Visit

The FBIM model has undergone continuous development by the AFAC FBIM project team since 1996, although it is recognised that the most significant period of development was during the late 1990s. A number of the original project team are still involved with AFAC and the FBIM while the remaining number have either retired or moved from the fire services into private industry. To provide the greatest depth possible to this research, the visit was organised with the intention of visiting as many of the original and latest project team members and to also visit a number of private fire engineering consultancies that currently utilise the FBIM as part of their work.

A total of 28 days were spent in Australia over 4 weeks with time spread across five Australian states. In total, 17 days were spent with five fire services and 5 days were spent with practicing fire engineering consultants. The following outlines the itinerary followed during the trip:

Week 1: South Australia and Australian Capital Territory:

South Australian Metropolitan Fire Service (Adelaide)

Defire Pty Ltd (Canberra)

Week 2: New South Wales – Sydney:

New South Wales Fire Brigade

Fire Engineering Professionals

Week 3: Victoria – Melbourne:

Metropolitan Fire and Emergency Services Board

Country Fire Authority

Bodycote Warrington fire (Aus) Pty Ltd

Week 4: Queensland – Brisbane:

Queensland Fire and Rescue Service

Connell Wagner Pty Ltd

Arup Fire Engineering

6.3. Analysis Methods

The intention of the research trip was to understand how the model was being applied throughout Australia given the different regulatory environments applicable to each state and to understand how the different fire services are using and applying the model given their different legislated roles in both fire service operations, design review and post incident/fire investigation. Similar differences were also relevant to the consultancies visited given that they were based in different states and had a different level of understanding of fire service operations and opinions on the needs and use of the FBIM.

The most important aspect of the trip was to gain as much exposure as possible to the people using the model and those working within the environment to which the FBIM is applicable. The time spent with the individual fire services depended on a number of aspects including their availability to accommodate the author, the size of the brigade and the exposure or knowledge of the FBIM throughout the brigades. It was quickly established that these factors differed considerably between the various brigades visited. In the context of the FBIM, reasons for this are likely to be directly related to the number and complexity of buildings being developed within the individual states and the role of the brigade, i.e. urban versus rural.

In an attempt to understand how the FBIM was being applied, the author used a number of methods to collect and build on this understanding. These included the following.

- A number of pre-set questions aimed at the fire service's fire engineers and fire safety staff/operational staff.
- A number of pre-set questions aimed at the design consultants.
- Meetings with the various fire service departments/staff members that may or may not be involved or have knowledge of the FBIM, including fire safety, fire investigation and operational departments.
- Where possible, sitting in on design meetings (Fire Engineering Design Briefs) to see how the design environment compares to that in New Zealand.
- Reviewing past examples of designs that have utilised the FBIM.

6.4. Australasian Regulatory Environment

To understand how the FBIM is being used within Australia by the various state-based fire services and practicing consultants it is important to understand the legal environment in which the FBIM is being applied. The Commonwealth of Australia is made up of six states and two major mainland territories, each with their own individual legislation comprising of Acts and Regulations. The Constitution of Australia states that responsibility for emergency responses lies with each of the states and territories. This includes preparedness for and mitigation of potential emergencies, as well as response and recovery action. Therefore each state fire service operates under different Acts, and has different requirements and levels of involvement with building design review, dependent on the legislation.

To appreciate how the FBIM is applied by each of the fire services and consultants it is important to understand both the relevant Fire Services Acts which empower the fire service to undertake fire-fighting operations, and the relevant Building Acts, which require the fire services to be involved in the building design process, either as an approval or review-only authority.

Appendix C provides the relevant state legislation under which the brigades operate in more detail. The following sections provide an introduction and briefly describe each of the Acts relevant to the fire services visited compared with those relevant to the NZFS and how each of the fire services operates under that legislation so that the reader can make a comparison with the NZFS.

It quickly became apparent that understanding the legislation under which each brigade operated was a major factor that influenced the use of the FBIM both within the individual state fire service and by the designers using the model depending on what state they were operating in.

Website addresses have also been provided for further information on those brigades visited:

South Australian Metropolitan Fire Service – http://www.samfs.sa.gov.au/

New South Wales Fire Brigade – http://www.nswfb.nsw.gov.au/

Melbourne Fire & Emergency Services – http://www.mfb.vic.gov.au/

Country Fire Authority – http://www.cfa.vic.gov.au/

Queensland Fire and Rescue Service – http://www.fire.qld.gov.au/

6.4.1. South Australia

The state of South Australia contains two fire services, the South Australian Metropolitan Fire Service (MFS) and the South Australian Country Fire Service (SACFS).

The Country Fire Service is a statutory authority reporting through a board to the Minister and is responsible for preventing and suppressing fires and responding to other emergencies in rural South Australia. The Service works closely with Forestry South Australia and the South Australian National Parks and Wildlife Service, which both form brigades that operate as part of the Country Fire Service. The organisation comprises approximately 16,500 volunteers and 71 career employees operating from 431 brigades and six regional offices.

The MFS is the primary provider of structural fire-fighting services to the State of South Australia. The MFS was established in 1867 and is based in the capital of South Australia, Adelaide, which has a population of approximately 1.2 million. The MFS employs more than 1,000 staff across 36 stations (19 metropolitan and 17 regional), which comprise approximately 770 career employees and 207 retained (part-time) fire fighters.

As only the MFS were visited during this research this section only focuses on information relevant to the MFS.

6.4.1.1. South Australian Metropolitan Fire Service

The Built Environment section of the Community Safety Department is responsible for overseeing building designs. The department is currently made up of community safety officers and a fire safety engineer who provides specialist engineering advice to the department. My time at the MFS was primarily spent with the current MFS fire engineer, Amy Seppelt, and Roger Marchant, now retired, who was the previous MFS fire engineer and one of the original FBIM developers.

6.4.1.2. Relevant Legislation

The MFS is governed by the South Australian Fire and Emergency Services Act 2005. This Act places specific functions on the MFS including those concerning the protection of life, property and the environment. This is the newest of all the Australian fire services Acts and specifically includes reference to protection of the environment, which forms part of the FBIM.

The South Australia Development Regulations 2008, under the Development Act 1993, provides for the involvement of MFS under two distinct sections. The first involves the referral of the building design for assessment under regulation 28 to ensure the design is adequate, and the second requires the MFS to produce an occupancy report on the adequacy of specific fire service installations such as the fire alarm system and booster assemblies (hydrants).

The reports provided by the MFS specifically state that the building design is fit for purpose from a fire-fighting perspective and also requires that certain systems (including any system installed for fire detection, fire fighting, sound and intercom for emergency purposes, or smoke control) should be inspected by the MFS prior to the issuing of a Certificate of Occupancy. This is important with regards to the FBIM as the MFS are legislatively empowered to provide comment on these facilities and to ensure that they meet with their satisfaction and, in particular, are commensurate with the operational fire-fighting requirements of the MFS. Given the liability issues that would be placed upon the building authority without the acceptance from the MFS this effectively means that buildings will not be allowed to be occupied unless the design meets with the approval of the MFS.

6.4.1.3. Guidance Documents

To support their legislative role, the MFS provide guidelines with respect to fire engineering and alternative solutions (46). The FBIM is specifically referenced within section 4 of these guidelines as given below.

> *4. Fire Service Intervention.*
>
> *It may be necessary to undertake a Fire Service Intervention analysis to demonstrate compliance with the BCA with respect to an acceptable level of safety for the building occupants. The ability of fire fighters to rescue trapped or mobility impaired building occupants and prevent fire spread to adjoining property are fundamental objectives of the BCA. **The Australasian Fire Authorities Council Fire Brigade Intervention Model should be used to undertake such an analysis.** This Department will assist designers to undertake such an analysis* (emphasis added).

6.4.2. New South Wales

Emergency management in NSW is the province of a number of government organisations, the NSW Rural Fire Service, the NSW Fire Brigade, the State Emergency Service, the Ambulance Service of NSW and the NSW Police Service. Each organisation has a separate administrative structure and reports directly to the responsible Minister.

The NSW Rural Fire Service is responsible for the prevention and suppression of bush and structural fires within its legislative areas, covering over 90% of the State. It is the designated agency for the management, coordination and suppression of all rural fires and achieves this by working closely with the NSW Fire Brigade, the National Parks and Wildlife Service and State Forests. The Rural Fire Service is responsible for the coordination of all agencies in a major bushfire.

The Rural Fire Service has 2,400 brigades throughout the State. Volunteer membership is listed as approximately 70,000 people and there are 482 permanent staff. The Service has divided the State into four regions: North, South, East and West, with 141 districts reflecting local government boundaries. The Australian Capital Territory is located within the NSW Fire District of Yarrowlumla, which reports to the Southern Region based in Batemans Bay.

As only the New South Wales Fire Brigade (NSWFB) was visited during this research, this section only focuses on information relevant to the NSWFB.

6.4.2.1. New South Wales Fire Brigade

The NSWFB maintains both permanent (full-time) stations and retained (part-time) stations. Community fire units have been introduced in some urban bush land interface areas, providing limited equipment and training to local residents.

The NSWFB prevents and responds to fires, hazardous material incidents, rescues and other emergency incidents within its legislative area, which comprises the Greater Sydney area and regional centres. It has 3,090 full-time and 3,198 part-time fire fighters at 337 stations across the State. Together with the NSW Rural Fire Service, the Brigade provides significant integrated support to communities in the urban–rural interface.

During this trip, time was spent within the Community Safety Division (CSD) and primarily with the Structural Fire Safety Unit. At the time of this research this unit had three dedicated fire engineers to provide specialist advice to the CSD and provide comment on building design submissions.

6.4.3. Relevant Legislation

The NSW Fire Services Act 1989 places emphasis on the duty to deal with fires and hazardous material incidents. The Act requires that all practicable measures for preventing and extinguishing fires and protecting and saving life and property be taken. No specific reference is made to the protection of the environment; however, the NSWFB is obliged to comply with section 10A – Protection of the Environment, which states that the commissioner is to have regard to the principles of ecologically sustainable development in carrying out any function that affects the environment.

The Environmental Planning and Assessment (EP&A) Regulation 2000 made under the Environmental Planning and Assessment Act 1979 provides for the NSWFB to be involved at both the design stage and pre-occupation stage of a building. Section 144 requires that an '*initial fire safety report'* be provided to the certifying authority within 23 days after receiving an application for construction for certain types of building. The EP&A regulation also then requires the certifying authority to provide written notice to the NSWFB if they decide to ignore the advice provided or continue with the application if no report has been provided by the NSWFB within the 23-day requirement.

The NSWFB comments on certain Alternative Solutions only, which include:

- Only Category 2 fire safety provisions which include
    - CP9 Fire service access around buildings
    - EP1.3 Hydrant systems
    - EP1.4 Fire suppression systems
    - EP1.6 Co-ordination centre for Brigades
    - EP2.2 Protection of Evacuation routes
    - EP3.2 Emergency lifts
- Class 9a (health-care buildings) buildings over 2,000 square metres
- Any building with a fire compartment over 2,000 square metres
- Any building with a total floor area exceeding 6,000 square metres

Section A0.8 of the Guide to the BCA (34) defines an Alternative Solution as the method which may be used to demonstrate the Performance Requirements of the BCA via a route which is not included in a *Deemed-to-Satisfy* Provision.

Specific commentary is required to be provided in relation to access to hydrant systems and compatibility of couplings for Brigade use. Prior to occupation of a building the NSWFB are then provided with the opportunity to provide a '*final fire safety report'* specifically commenting on compliance of any hydrant system provided and Category 2 fire safety provisions. This also includes an inspection under clause 152 to verify if the Section 144 solutions are installed and operate as assessed.

6.4.3.1. Guidance Documents

The NSWFB also provide guidelines with respect to certain building types (47). Reference to the FBIM and expectations relating to fire brigade intervention within building designs can be seen in the following extract:

Consideration for fire service intervention and conditions need to be evaluated at the anticipated arrival time, as calculated through acceptable fire service intervention modelling. The model duration may also be required to be extended to incorporate conditions at the anticipated arrival time, following evaluation of the anticipated arrival time.

This guidance then goes on to require that fire engineering reports are required to contain drawings and technical data which specifically includes reference to an FBIM evaluation.

6.4.4. Victoria

Emergency management in Victoria is the responsibility of a number of different organisations, the Metropolitan Fire Brigade, the Country Fire Authority, the State Emergency Service and the Ambulance Service Victoria. Both the Metropolitan fire service and the Country Fire Authority were visited while in Victoria.

6.4.4.1. Metropolitan Fire and Emergency Services Board

The Melbourne Metropolitan Fire Brigade (MFB) is managed by the Metropolitan Fire and Emergency Services Board (MFESB) and covers over 1,000 square kilometres of area mainly consisting of the city of Melbourne.

The MFB has approximately 1,511 professional fire fighters and is supported by a number of technical and administrative staff. The MFB fire fighters are also the first to respond to specific medical emergencies under the Emergency Medical Response First Responder Program, the first of its kind in Australia.

The MFB currently employ a range of fire engineers, risk engineers and code consultants to provide specialist advice to the Community Safety Department which undertakes building design reviews.

6.4.4.2. Country Fire Authority

The Country Fire Authority is a community-based fire service providing fire and emergency services to rural and provincial communities, as well as urban Melbourne communities outside the Metropolitan Fire and Emergency Services Board legislative district. The CFA is one of the world's largest volunteer-based emergency services. There are around 60,000 volunteer members supported by over 500 career fire fighters and officers and more than 900 career support and administrative staff.

Situated in Victoria, there are 2.5 million people and 150,182 square kilometres of land in the CFA area. This area includes more than 980,000 homes, and covers all of rural Victoria, and the provincial cities and towns (except State forests and National Parks).

CFA divide the land covered into nine CFA Areas and 20 Regions. Across these areas there are over 1200 CFA brigades across the state which carry out a wide range of duties.

The CFA have only recently employed their first full time fire engineer dedicated to providing specialist advice to the Structural Fire Safety department within their Community Safety Division. Prior to this, fire engineering advice was provided both in house and outsourced as necessary.

Although the CFA is typically thought of as a rural fire service, their boundaries and areas of jurisdiction cover many urban areas and due to urban sprawl over the last couple of decades increasingly cover more urban type risks which overlap with the MFB.

6.4.4.3. Relevant Legislation

The Metropolitan Fire Services Act 1958 requires that the MFB use all practical means to protect any persons or property that may be endangered by fire. No specific reference to environmental protection is made within the Act. However, the MFB have policies in place referencing other state legislation that places an emphasis on the need to protect the environment.

Under the *Country Fire Authority Act 1958* ('the CFA Act'), the CFA is vested with the duty of *"taking, superintending and enforcing all necessary steps for the prevention and suppression of fires and for the protection of life and property in case of fire...so far as relates to the country area of Victoria".* This includes wildfires and structure fires, as well as incidents involving hazardous materials, road rescue and rescue in areas of diverse risk, including high-risk industries such as petrochemical and gas.

Under the national Building Act 1993 and Building Regulations 2006, the fire services can enforce fire safety maintenance requirements within existing commercial buildings, as well as specific fire safety standards within certain existing residential buildings. The Chief Officer is authorised under Section 255 of the Building Act 1993 to issue an official warning or building infringement notice for prescribed offences.

Under Regulation 309 of the Victorian Building Regulations, consent of the Chief Officer must be obtained if a building is proposed where any of the following fire safety matters do not meet the deemed-to-satisfy provisions of the BCA:

(a) fire hydrants;

(b) fire hose reels;

(c) fire control centres or fire control rooms;

(d) fire precautions during construction;

(e) fire mains;

(f) control valves;

(g) booster assemblies;

(h) emergency vehicle access;

(i) fire indicator panels;

(j) proscenium curtain drencher systems;

(k) fire services controls in passenger lift cars.

As can be seen, the involvement of the Victorian brigades is only triggered by an alteration to a fire-service-related feature. This means that if designs contain alternative solutions to other aspects of the building design the brigades are not afforded the opportunity to review those designs. However, the reports that are reviewed are done so on an holistic basis, which means that they will also provide comment and potentially refuse to accept any deviations if alternative solutions are proposed on other building design features, e.g. structural stability of the building.

6.4.4.4. Guidance Documents

Of all the fire services, the MFB provides more guidance documents relating to the design of buildings than any other. Although most Australian brigades provide guidance on their involvement in the design review process and provide generic guidance on their expectations for alternative and performance-based designs, the MFB provides numerous guidance documents (48) for specific applications including performance-based designs. The MFB also provide policy documents, one of which is specific to performance-based designs and fire service requirements (49). With specific reference to fire brigade intervention, the MFB policy document states:

> *As a minimum, the following issues are required to be addressed for the purpose of fire service intervention:*
>
> *Fire fighters must be given a reasonable time to enter buildings to conduct search and rescue activities for occupants and to carry out internal fire-fighting attack before hazardous conditions occur and prior to building collapse; and*
>
> *In addition, fire fighters should be provided with the necessary information, control and safety systems, equipment and fire-fighting medium to effectively suppress and carry out fire-fighting activities.*

Fire Safety Guidelines GL-17(50) is specifically dedicated to the FBIM, and due to its relevance is contained within Appendix D. Of significance is the requirement to meet the performance requirements of the Australian Building Code "*to the degree necessary*".

- Given a reasonable time to rescue occupants prior to hazardous conditions and building collapse.
- Be provided with the necessary equipment, systems and water quantities to effectively carry out fire-fighting activities.

The CFA are currently drafting a policy guidance document on alternative and performance-based designs that will require their endorsement. It is expected that like the MFB guidelines this document will have specific reference to the FBIM.

6.4.5. Queensland

Queensland has a single Department of Emergency Services that is responsible for emergency services and emergency management throughout the state. The Department covers all areas concerned with the prevention of, preparation for, response to and recovery from all types of emergencies delivered by the Queensland Fire and Rescue Service (QFRS), the Queensland Ambulance Service and the Counter Disaster and Rescue Service.

6.4.5.1. Queensland Fire and Rescue Service

The QFRS combines urban and rural services employing approximately 1,916 full-time and 1,952 part-time (auxiliary) fire fighters to staff over 240 urban stations. Approximately 45,000 volunteer fire fighters make up the State's 1,623 rural fire services.

As part of the standard building approvals process in Queensland, the QFRS is a referral agency for all performance-based Alternative Solutions that involve fire safety designs. These referrals are generally dealt with by a number of building approval officers in the various regions around the state.

Of all the brigades visited, the QFRS were the only brigade to not have a centrally located department solely responsible for building review work. Two fire engineers are specifically employed within the fire engineering section of the Community Safety Department. However, they provide more of a support function role to the significant number of regionally based Building Assessment Officials who review building designs and consent applications.

6.4.5.2. Relevant Legislation

The Queensland Fire and Rescue Service Act 1990 specifically stipulates that the functions of the QFRS are to protect persons, property and the environment from fire and hazardous materials emergencies.

Schedule 2 of the Integrated Planning Regulation 1998 sets out the building approvals process and requirements for the involvement of the QFRS. These regulations require that any application made for building approval that proposes an Alternative Solution for a fire safety system that is to be assessed against the Performance Requirements of Volume 1 of the BCA must be referred to the QFRS for advice. This schedule also includes specific reference to residential care and budget accommodation buildings.

The QFRS also has stronger powers of enforcement to ensure adequate fire safety standards are maintained than most other fire services. This includes an ‘on-the-spot’ fines system that commenced on 1st December 2001.

6.4.5.3. Guidance Documents

The QFRS Policy on Fire Engineered Alternative Solutions (51) provides guidance to engineers and designers with regards to the required content of alternative designs and the consultation process. Of specific note is that under the heading of the Fire and Rescue Service Act this policy requires that:

> *Performance-based alternative solutions must incorporate the following objectives:*
>
> *Fire service intervention – fire fighters must be given reasonable time to enter buildings to conduct search and rescue activities for occupants and to carry out internal fire-fighting attack before hazardous conditions occur and prior to building collapse.*
>
> *The design of fire safety systems must facilitate safe and efficient fire service intervention.*

6.4.6. Private Building Certifiers

One significant difference between the New Zealand and Australian design environment is the presence of private building certifiers who act on behalf of the local councils. Unlike in New Zealand where all Building Consent applications are approved by the relevant Building Consent Authority, in Australia building approvals and the design processes are increasingly being made by private certifiers. It is understood from the research undertaken that the insurance and liability issues faced by private certifiers has increased the level of caution exercised as part of the consent process. As a result, alternative designs accepted by a certifier appear to be far more rigorous in the level of justification required than appears to be the case in New Zealand. Also, any comment made by a fire service on an alternative design needs to be very carefully considered by any certifier as they may ultimately carry the risk and liability should they ignore the fire service and any consequence resulting from the alternative solution accepted.

6.4.7. Building Legislation and the FBIM

Although Australia has one Building Code applicable to the entire country, the way in which building design is enforced, especially from a fire brigade perspective, differs significantly from state to state. From the short period of time spent with the brigades and reviewing reports and issues faced by them, it would appear that the degree to which fire-fighting facilities and alternative designs that affect fire brigade intervention are being altered from the prescriptive solutions depends on the respective fire brigade's level of involvement in the design review process and also on their respective enforcement powers, either at the design stage or occupation of the building or both.

There would appear to be a direct correlation between how 'effective' a fire service is at enforcing building legislation and their own requirements and how often, and to what degree, designers are deviating from prescriptive requirements.

In simplistic terms, the Australian fire brigades have more enforcement powers during the design review stage and have greater powers of Building Code enforcement once a building is occupied than the NZFS appears to. The upshot of this is that it is more difficult to propose an alternative solution and almost impossible to get consent if the fire brigade does not accept the solution. If the alternative solution involves changes or removal of a fire-fighting feature this will almost certainly get rejected unless the fire brigade approves its removal. Should the alternative solution be approved against the advice of the fire services there are also implications on completion of the building if the fire services are not satisfied that the building complies, as action can be taken at that stage to rectify the situation. This means that there are significant deterrents to building developers both in terms of project delays and additional costs associated with designs that do not meet with the approvals of the relevant brigades. Therefore, building designers and especially developers appear to be more cautious about deviating from prescriptive solutions than is the case in New Zealand. This appears to result in a more risk-adverse design environment, which encourages and supports early liaison and consultation during the design stages of the project.

Notwithstanding this, the widespread knowledge and use of the FBIM is such that there is an accepted approach to dealing with deviations that affect fire service intervention. Although it is quite possible to utilise the FBIM to justify alternative solutions, the cost associated with doing so immediately means that there are less advantages of proposing such alternatives. This would appear to be directly opposed to the current situation in New Zealand where there is no currently accepted methodology of quantifying such alternatives, and engineers' opinion is typically the only form of justification used where there are less controls on such proposals. Therefore, with less regulatory risk it can be seen why in New Zealand more designers propose such deviations and why there is very little cost associated with such proposals. Additionally, an iterative design process appears acceptable to many during the design process even though this is contrary to the Building Act.

One of the most important conclusions taken from this research is that the FBIM serves as a check and balance of the design and as a deterrent to designers to undertake alternative designs that impact on fire-fighting requirements. Whether or not the FBIM is being used specifically within designs, its presence within the design environment in Australia ensures that the fire services become involved in the design process to ensure that they are not overlooked or unduly affected by any proposed alternative designs.

6.5. Australian Experience of the FBIM

As could be expected, the opinions formed by individuals or indeed entire companies was found to be based on their level of exposure and understanding (through training or experience) to the FBIM and, importantly, the environment in which they utilise the FBIM. In other words '*why is the FBIM being used*?'

The following findings are based on the questions asked of each of the fire services and consultants. The specific questions and answers provided by those interviewed are not documented here to avoid identification of any particular individual or fire brigade but are summarised below based on the authors opinions of the findings.

6.5.1. Exposure and Knowledge of the FBIM Throughout the Fire Services

The number of persons within each of the fire services who had knowledge of the FBIM and experience of its use in a practical sense varied significantly between the brigades. Those with knowledge of the model ranged from selected individuals within the brigades, typically limited to the fire engineers or selected fire safety officers, to widespread knowledge of the model throughout the respective safety, fire investigation and operational departments.

Such differences appear to be dependent on the size of the safety departments in relation to the size of the built environment within the state and the level of control and legislated role of the fire service when it comes to assessing building designs and fire-fighting issues.

For example, there is a significant difference in the size and nature of the buildings being constructed and designed, say in Sydney when compared with Adelaide. The legislation and way in which the brigades become involved in designs also differs, which as a result defines how the fire service's relationship with the design fraternity functions.

6.6. When and Where to Use the FBIM

"Should the FBIM be used or enforced every time there is a departure from the prescriptive compliance documents and every time an alternative departure from codes or standards is proposed"?

The simple answer to the above question was found by both fire brigades and designers to be clearly – no!

The FBIM should not be used in every situation where a deviation from the prescriptive requirements is proposed and fire services should in some respects discourage the use of the FBIM unless considered necessary or a full performance-based design approach is adopted. In most sprinkled building designs the fire service should be comfortable that the proposed design will generally meet with the objectives and legislated requirements of the fire service. Providing significant deviations involving fire-fighting facilities such as sprinklers would almost certainly trigger the requirement to undertake an FBIM analysis. However, were only minor deviations from the prescriptive requirements proposed, early consultation should be promoted to encourage designers to discuss their proposals with the fire service so that agreements can be made as to acceptance of the deviations.

However, what needs to be stressed is that no fire service, which includes the NZFS, should accept any deviation from the prescriptive solutions unless an appropriate level of justification is provided to support the deviation. The FBIM should be used to support such justification and to show that fire brigade intervention will not be adversely affected by any proposed deviations. An FBIM analysis, however, can be time consuming and relatively expensive from a consultant's perspective and so should only be considered if the deviation warrants such time and cost expense.

6.6.1. Minor Deviations from the 'Deemed-to-Satisfy' Provisions of the BCA

The FBIM was never intended to be used in every situation where there is a departure from the prescriptive requirements, nor does it need to be used in every case where a minor departure is proposed. It is essential, however, that discussions be held with the fire service over any proposals to understand if the variation has any effect upon fire brigade intervention and to what extent the effect may be.

No fire service visited was found to be requesting or requiring a designer to go through the FBIM process for every design in which a departure from the 'Deemed-to-Satisfy' requirements occurs. Small deviations that only have minor effects on the fire service to undertake their statutory duties, as in New Zealand, are typically addressed by discussions directly with the fire service and resolved using qualitative descriptions of the effects and reasoning behind what effects the deviations will have upon the fire service's ability to respond and intervene.

For example, small increases in escape route lengths above the prescriptive requirements may not have a significant impact upon fire service activities. In such situations the designer may or may not be proposing additional compensatory features or can readily qualitatively describe why the building has features that alleviate the minor deviations as proposed.

However, it must be stressed that in such circumstances, discussions must be held and agreements made with the fire service to ensure that they are in a position to accept and support such deviations. It is further stressed that any such discussions and any agreements made need to be fully documented by the designer within the documentation required to demonstrate compliance with the relevant BCA performance requirements. It was found to be increasingly important for the fire services to understand and thus require that any deviations be fully documented by the designer/proposer and that an appropriate level of justification be provided so that any decision made is based on sound technical justification.

In conclusion, no fire service would support any deviation without first being provided with the appropriate level of justification and documentation on which to base any decision.

6.6.1.1. Selected Use of the FBIM Methodology

Because the FBIM covers all fire-fighter activities from the time of arrival at an incident through to extinguishment and overhaul, and environmental protection, application of the entire model to every situation may not be necessary. Where minor or very specific deviations are proposed that only affect clearly defined aspects of fire brigade intervention, the FBIM may only be required to be analysed until that aspect has been investigated and proven. The model should also be seen as a flexible tool in that only those aspects affecting the essential intervention aspects need to be taken into account within the analysis.

It would not be expected, for example, to assess the actions of multiple appliances and their attendance at an incident where the FBIM assessment was only required to understand the arrival or set up times associated with a single pumping appliance. Additional appliances and fire fighters present at the scene, whilst providing additional responses, equipment and resources to the incident, could be ancillary to the appliance and fire fighters who would likely arrive first and be of principle interest to the analysis.

Also, the analysis may only need to be undertaken up to a point of specific interest as agreed with the respective brigade. For example, depending on the alternative solutions proposed, the fire brigade may only be primarily interested in ensuring that the fire is within the fire suppression capability of the closest responding appliances. In this situation, only the predicted arrival time versus fire development may be of interest. However, should the alternative solution modify smoke extraction and egress path lengths, for example, a fire brigade may wish to ensure that they would have sufficient time to be able to conduct search and rescue activities within a certain area of the building before untenable conditions for fire fighters were reached.

6.6.2. FBIM Application

Application of the FBIM differs slightly from state to state and it appears dependent on how each fire service becomes involved with the design. More often than not, FEBs are requested by the consultants early in the design phase. FEBs are a regular occurrence throughout Australia on most, if not all, designs that propose significant alterations to the ‘deemed-to-satisfy’ requirements. The IFEG FEB process is strongly reinforced by all the brigades and is written into most guidance documents and policies provided by the Australian brigades as to their expectations of involvement in the design process. As part of the FEB process, the IFEG requires assessment of fire service intervention; as such, the liaison with brigades becomes a formality in most designs. Dependent on the scale and scope of the project, the need to undertake an FBIM analysis will typically be discussed, including the parameters and expectations of the analysis. It is important to note that in most if not all of the brigades, the FEB meeting is attended by at least two fire brigade staff, typically those with appropriate experience in operational matters, fire safety and fire engineering. With this range of experience and knowledge, a decision can normally be made as to whether the designs proposed will require an assessment using the FBIM.

An FEB meeting is important for all the stakeholders as it provides the fire brigade with an opportunity to understand the requirements and needs of the architects and client and also the methods proposed by the fire engineers of how they intend to address the alternative solutions. Once the fire brigade has a clear understanding of the issues it should be in a position to either recommend that an FBIM assessment will be required or to discuss alternative methods if such an analysis is unnecessary.

Once the need for an FBIM is clearly established, the parameters required and information needed by the consultant to undertake the FBIM can be discussed. Depending on the nature of the proposal, these need not be detailed as the FBIM manual contains enough data for the assessment to be run without further input from the fire service. In these circumstances, discussions and checking by the brigades only need to be undertaken on the assumptions made within the model and assessment undertaken based on the individual brigade's standard operational procedures.

Where designs are brought to the fire brigades on the basis that an FBIM will be required, again discussions can be held over any significant issues that the fire service believes relevant to the proposal, otherwise assessments can be submitted electronically or by other means so that the fire service can check and verify that the results are meaningful.

There are a number of essential elements that are required to make sure that an FBIM analysis is first of all needed and secondly beneficial to all the stakeholders. Following a proper process and undertaking an FEB is essential to gaining fire service approval for the project design basis. Secondly, if an FBIM is required and if an FBIM cannot be avoided by other means it should ensure that any analysis is fit for purpose. The most important aspect of this whole process however, is that the fire services endeavour to provide the three key ingredients to the process. Without the appropriate knowledge in operational matters, fire safety and fire engineering, the process runs the risk of not identifying important issues that could affect the fire brigade intervention requirements for the building.

6.6.3. FBIM Education and Training

If the FBIM was to be used appropriately then education and training in its use was found to be essential(1). During development of the FBIM it became obvious that a combination of knowledge of both fire-service operations and fire-engineering principles would be required.

The FBIM committee has maintained a broad range of skills and backgrounds including those in fire brigade operations and fire engineering, and so the FBIM was developed with the intention of assisting both the fire service and fire industry with assessment of performance-based designs. The FBIM committee acknowledged that if the fire industry lacked knowledge of fire brigade operations they would require training. Likewise, the fire service would require training in fire engineering to ensure that they would understand the FBIM and could provide relevant input into the engineering aspects associated with performance-based designs. Once both parties obtain the appropriate level of knowledge, specific training can then be given in the mechanics of the FBIM and its application to performance-based designs. This was recognised in a paper discussing the FBIM presented at the 1st International Conference on Fire Service Deployment Analysis in 1999 (52). Of relevance was the reference to the NZFS providing training material to support the Training Package being developed at that time.

Tertiary education and formal training is provided in Australia by three universities in Victoria, New South Wales and South Australia that provide courses specifically regarding fire brigade operations based around the FBIM.

Victoria University provides three fire engineering courses including a Master of Engineering in Building Fire Safety and Risk Engineering, a Graduate Diploma in Building Fire Safety and Risk Engineering and a Graduate Certificate in Performance-Based Building and Fire Codes. A paper covering fire brigade response and operations is taught on all three courses which includes presentations given by the MFB on the FBIM.

The University of Adelaide does not provide a specific fire engineering qualification, but as part of its Mechanical Engineering degree provides a fire engineering course that specifically covers the FBIM. This course is given by Roger Marchant, formally of the MFS.

The University of Western Sydney provides both a Graduate Diploma and Masters Degree in Fire Safety Engineering. A specific course on fire brigade intervention and operations based on the FBIM is taught.

From these findings it is considered that education of the FBIM or at least its general principles is essential if it is to be used properly within New Zealand.

6.6.4. Who Can Use the FBIM

As part of the requirements to use the FBIM it is recognised that it should always be conducted in liaison and/or verified with the relevant fire service's fire safety/engineering department. Use of the FBIM in Australia to date indicates that only those individuals with sufficient knowledge of fire service operations can fully appreciate the inputs required to support the FBIM appropriately. If persons unfamiliar with fire service operations use the FBIM, the analysis risks becoming irrelevant or worse, dangerous. To support the FBIM appropriately, any fire service using the FBIM or offering advice on its application should be well informed on its use within a performance-based design environment. Likewise, a designer using the FBIM who has little or no understanding of fire service operations in and around buildings may produce meaningless or undesirable results. However, to aid in the application of the FBIM, AFAC produced the FBIM computer program intended to reduce the misapplication of the FBIM methodology. As with any computer package or design application, however, a fundamental understanding of its basis and education of its application are still essential to achieving the appropriate results.

6.6.5. Concerns Raised With the Use of the FBIM

As with any model used within fire engineering there is scope for misuse, be it intentional or otherwise. Alexandrovski (1) researched the use of the FBIM and whether it was being appropriately applied within NSW. Findings of the author and those of the NSWFB would suggest that they both have concerns that the FBIM is not being consistently applied and in accordance with an appropriate fire engineering process such as the IFEG (14). The results of such concerns were that assumptions made within the FBIMs presented by consultants were inconsistent with the Standard Operational Procedures of the NSWFB and that they lacked proper contextual value.

Time spent with Alexander Alexandrovski as part of this research trip and reading through his research material provided reasons for why the model is not being used as intended. The main reason for this would appear to be a lack of understanding of fire service operations and the effect that any deviations in building designs will have upon fire service operations. From this perspective it can be seen that involvement of the appropriate fire services operational personnel is crucial to a successful outcome of the FBIM.

6.6.6. Fire Services Providing an FBIM 'Consultancy' Service

The FBIM requires knowledge of fire service operations, current fire service capabilities and response characteristics as well as fire engineering knowledge. Fire brigades themselves are seen to be in a key position to not only offer advice on the model and undertake a review but also to provide the assessment on behalf of the consultant for a fee. At this time, only the MFB offer such a service to the design community and will provide an FBIM analysis by charging for this service. It is understood that the MFB have undertaken the analysis on a number of occasions but that this has not been done for some time. It would appear from the anecdotal evidence that such analyses were undertaken when the FBIM was first starting to be required by the brigades. The analyses were typically undertaken for consultants with little or no knowledge of the FBIM. These consultancies have since stopped requesting such assistance given that they now have the model and the experience in its use and application for building designs. The market for such assessment from a fire service perspective would therefore be somewhat limited.

The NSWFB are also considering charging for similar advice but are not currently doing so. Research undertaken by Alexandrovski (1) in association with the NSWFB suggests that the FBIM is not being applied as intended, and this is a key driver behind the NSWFB considering providing such a service. However, the author of this project is not in favour of this approach as it removes fire brigades’ independence from the design process. Such independence is considered important to ensure that any fire service does not unreasonably drive the design requirements of a building and to ensure that they do not become liable for aspects of the design which should be the responsibility of a professional design engineer.

6.6.7. Other Uses of the FBIM

6.6.7.1. Use of the FBIM in Building Appeals Processes

Similar to the Determination process in New Zealand, the building appeals process in Australia is used to determine compliance against the BCA if any of the parties involved in the building design, such as the developer, private certifier or fire service raise a matter of dispute over a compliance issue. The FBIM has been successfully used on a number of occasions, particularly by the MFB, to argue and show that fire brigade intervention requirements have not been met within the proposed design.

Although the NZFS has taken a number of determinations relevant to fire brigade intervention, it has not to date referenced or used the FBIM to argue any matters of dispute. Although not necessary in any cases in the determinations to date, an FBIM analysis could have been used to illustrate issues within the building's design relevant to any matters of dispute.

6.6.7.2. Use of the FBIM for Post-Incident Analysis and Fire Investigation

As the FBIM quantifies fire brigade operations and provides a time line of the anticipated events at an incident, it is possible that the FBIM can be used for more than just building designs. Although the use of the FBIM for these types of applications is not widespread and relatively rarely used, a number of fire services have either used the FBIM for post-incident analysis purposes or are considering incorporating such an analysis of part of an operational review if required.

Given that the FBIM provides an accepted methodology to quantify fire brigade operations, it is understood to have been successfully used on a number of occasions to support the times taken for fire brigade operations at incidents. Such analyses have been undertaken where the fire brigades have found themselves subject to criticism regarding the length of time it has taken them to respond and undertake certain activities at emergency incidents. Where the FBIM has been used for this particular purpose it is understood that, on each occasion, issues such as travel times to the incidents and times taken to set up and access and assess the situation were not unexpected to members with operational experience and were within accepted fire service response policies. However, at some incidents the fire services have been criticised that their response was perceived to be below that expected of them. In such cases the FBIM model has been assessed based on the incident and the operations undertaken at the time compared with those assumed within the model and the times predicted by the outcome. Although it was never intended for the FBIM to be used as a design approach to influence fire service operational decisions, the outcome of such analysis is that the times associated with the incidents were similar to those predicted by the model based on a certain percentile approach. The result of this type of application provided those brigades not only with evidence supporting the actions undertaken at those incidents but also substantiation of the times in which it took the fire services to carry out those actions.

It is also important to recognise that the use of the FBIM in this manner has served to validate the model and provide some confidence in the methodology and times provided to support it.

6.6.7.3. Tactical Command Training

It is not expected that the use of the FBIM as a design approach will influence fire service deployment decisions. However, use of the model for operational training purposes and pre-incident planning is a possibility being considered by some brigades. Although not tried or tested at this time, it is expected knowledge of the FBIM in joint use with training packages such as VECTOR Tactical Command training (53) could help officers gain a better understanding of the times associated with specific deployment decisions so that they could possibly use this to influence their decisions depending on how incidents are unfolding in real time.

6.7. Australian Research Findings

6.7.1. Fire Service Staff Opinions of the FBIM

It is clear after speaking with the various brigades and many individuals within those brigades that there is a wide and varying opinion about the FBIM and not all of it is positive. It is clear that the opinions expressed to the author have been made depending on the individual’s level of exposure to the FBIM and understanding of the model and the context to which it is being applied.

There are a number of variables that can explain why such a wide range of opinions exist within the brigades., including:

- *the respective state and fire services legislation and understanding of how the FBIM fits in with this legislation;*
- *the individual fire service's involvement in the building design process and the effect that this has upon the use of the FBIM in the design process;*
- *the individual's exposure to the FBIM including training and length of involvement with the FBIM;*
- *the individual's understanding of performance-based engineering and its effect upon the built environment;*
- *the enforcement powers of the individual fire services and use of these to lever the FBIM as a design tool as and when required.*

As the author's time with the brigades was mostly spent with staff members familiar with the FBIM, it could easily be argued that with regards to trying to gain a balanced view of the fire brigades opinion of the FBIM, the results would be biased. This is certainly true. However, mixed opinions were found amongst those persons talked to. Such opinions ranged from the belief that the model represented realistic fire brigade times as accurately as could be expected, to the other end of the scale where individuals believed that the times predicted by the model were typically excessive and not realistic. Some people considered that this type of model was unnecessary, while others considered it essential to the life safety of fire fighters.

There are a number of reasons why the author feels that concerns regarding the model exist, and why those individuals expressed such beliefs. An understanding of the design environment and the background to the FBIM is crucial to understanding why there is a need for the FBIM and why the model is structured in the way it is. The individuals who expressed concerns over the need for the FBIM and those that expressed concerns over the times predicted by the model did not appear to be greatly involved in the design or fire-safety field, i.e. they had little real experience in building design and the implications of performance-based design on fire-fighting operations or had not used the FBIM first hand in a challenging design environment.

An example of this is the belief that the FBIM does not reflect reality and that it predicts unrealistic and excessive intervention times. This opinion stems from operational experience and a belief that that the fire services should not promote and associate themselves with times that appear excessive and could be detrimental to the public's perception of their ability. However, as with any building design egress analysis, it is not appropriate to always consider best-case scenarios and times which are only attainable during normal conditions.

An example of how the FBIM should be applied, and in which the times can appear excessive, is considering the response times from fire stations given the proximity of the building to the fire station. If, for example, the building being analysed is only 100 m from the nearest fire station, it might not be appropriate to only assume a vehicle response distance of 100 m. Some scenarios might need to consider that the station is not manned at the time of an incident and that the appliance is not available as a result of it being committed to another incident, for example. A second fire station or even a third might need to be used for the FBIM analysis, increasing times from what a designer or even a fire service person might have expected. However, issues such as this need to be taken into account to ensure that a credible worst-case scenario is being considered.

6.7.2. Consultants' Views of Fire Brigade Intervention and the FBIM

As was to be expected, the opinions expressed by the consultants were variable. Disagreements arose over what actually constituted fire brigade intervention and to what degree fire service involvement was required within the building design process. A proportion of the consultants visited had fire service operational experience and their views were slightly more biased towards the needs of the fire services within designs. However, the common theme expressed by all those consultants was that they considered the fire services to be important stakeholders and as such needed to be incorporated in the design process.

Another significant difference that became apparent from the time spent with the consultants in Australia in comparison with the design fraternity in New Zealand is that the Australian fire engineers appear to reinforce fire-service requirements and see these as positive design factors. An example would be hose run distances from hydrant outlets and the acknowledgement from consultants that distances prescribed by building codes are 'maximums' as they reflect the upper limit of capabilities during intervention and not the minimum. Typically, extending hose run distances is not acceptable and so it is not possible to extend means-of-escape travel distances significantly, even if analysis can show this is acceptable.

During the time with the Australian fire services the author was given the opportunity to sit in on FEB meetings. The previous view was reinforced within these meetings as the consultants appeared to respect and understand the needs of the fire services. The FBIM was not specifically discussed within any of the meetings attended. However, the tone of the meetings and designs put forward were such that it was clear the consultants were spending considerable effort designing fire service facilities into the buildings rather than spending that effort trying to design them out.

All the consultants talked to had undertaken FBIM analysis for building projects they had worked on. However, the common view expressed between them was the desire not to have to undertake such analysis. This view was partly formed as a result of the added costs associated with undertaking the additional analysis but could also be put down to the opinions that they did not want to propose alterations that would ultimately affect fire service intervention.

6.7.3. Concerns Relating to the Assumptions Made Within the FBIM

A number of concerns have been raised by both fire brigades and designers over the values and assumptions that are made within an FBIM analysis should these assumptions change over time. For example, if travel times from a fire station are used within the model, concerns have been expressed as to the implications of moving the station location in the future. Similar issues are also relevant to other assumptions within the model that relate to the capabilities of the fire services with respect to resources and equipment and the implications of these changing over time. However, the assumptions on which the FBIM are based should not be that sensitive to changes that could be reasonably expected, including inputs such as fire station location. It should also be recognised that with any performance-based design, assumptions regarding the basis of the design have to be made. Therefore, defining fire-service operations does not mean that these are locked in for the remaining life of that building. If any significant changes do occur that alter the design base assumptions significantly, then as with other aspects of the design, these should be rechecked and the design changed accordingly.

Similarities with other building design aspects can be made, for example with water supplies. When a building is constructed the design of systems (including sprinkler systems) are typically based on the flows and pressures of the water infrastructure available at the time of construction. These may change over time as can be seen with water supplies and water companies which are reducing water supply pressures as much as possible for various reasons. This has an effect on sprinkler systems that may induce required changes and alterations to the systems to take such changes into account. To reduce the impact that such issues could create, appropriate safety factors need to be applied to an FBIM assessment. The involvement of appropriate fire service personnel should also help reduce such issues.

6.7.4. Use of the FBIM to Remove Fire-Fighting Facilities

Because the FBIM quantifies fire service activities, it could be possible using the FBIM to demonstrate that the fire services have sufficient time available to undertake required operations without using specific equipment. Such examples could include manipulating the model in an attempt to show that the fire service may have the time available to extend hoses through and up buildings without the need to use internal hydrant risers, for example. It should be stressed that this is not the intention of the FBIM and that no fire services were found to accept such an analysis in Australia. Many fire-fighting facilities including hydrant facilities are provided due to inherent limitations in the capabilities of fire service equipment and physical ability of fire fighters. A time-based analysis in this circumstance may not always be appropriate.

For example, fire hoses have the capability to be extended almost indefinitely to any length. However, practicable limitations exist given the safe working pressures of the hoses and pressure losses and also the limitations in the ability of fire fighters to manoeuvre hoses due to their increasing weight with increasing length. Such factors are not included within the FBIM as consultation with the local fire services should ensure that their standard operational procedures are followed which would incorporate any equipment limitations.

The FBIM should be seen solely as a tool for assessing fire-fighter safety given the proposed building design. If fire-fighter safety cannot be proven, the building design should be adapted accordingly. The FBIM should not, therefore, be used to remove or reduce the level of safety to fire fighters.

6.7.5. Buildings Reliant on Fire Service Response

The safety of occupants within buildings should never be predicated on the attendance of fire brigades and based on assumptions that persons will be rescued. This is identified within many performance-based codes throughout the world as identified in chapter 5. However, situations will always occur which require fire brigades to undertake rescue operations, and specific building types, such as hospitals and tall buildings, will always to some degree rely on fire brigade intervention in the event of a fire. However, a building design should ultimately be 'self sufficient' and not rely on fire brigade intervention. In the future, it is likely that the funding and strategic direction of fire services will change as a result of ever-increasing financial pressures and increasing efforts in other non-traditional emergency service responses, including environmental protection and vehicle incidents. This further enforces the intent of the FBIM in that it should be a tool used to assess the life safety of fire fighters and to facilitate their role rather than a means of designing these features out of the buildings. This argument may be perceived to be contradictory by some, but is an important aspect of the intended use of the model as it relies on fire services' standard operational procedures as a critical part of the analysis.

An example of this is the consideration of the fire service as an 'active suppression' system similar to that of a sprinkler system. For example, many building codes allow the reduction of fire ratings if sprinklers are provided. However, they do not remove the need for such ratings and typically only allow them to be halved, even though it could be shown that no ratings are required should the sprinkler system work. The redundancy provided in this requirement takes into account the fact that such systems are not 100% reliable and dismisses the actions of the fire services, even though it could be shown by the FBIM that a fire service could potentially suppress the fire, reducing the need for higher fire ratings. In this example, the FBIM could be used to argue that the fire service should be able to extinguish the fire in a given time given the resources available and thus determine any fire ratings on this basis. However, such a design approach would significantly deviate from any currently accepted design approaches and insufficient data is currently available that could clearly demonstrate that such an approach would be acceptable.

CHAPTER 7. New Zealand FBIM Data

7.1. Introduction

Response times to buildings and incidents have historically been perceived to be a key factor in the ability of emergency responders to effectively respond to fire. It is also apparent that in an emergency there is a public perception that when the emergency services arrive the situation will instantly be brought under control and made safe. It is becoming well known throughout emergency services worldwide that the time taken to reach the scene of a fire may not always represent the most significant proportion of the time taken for the fire brigade to commence fire fighting or rescue operations and start to bring about control over the situation. PD7974-5 (4) suggests that a time upwards of ten minutes can be expected between arrival and commencement of fire-fighting activities in a high-rise building. However, fire station location and resource allocation are in many cases still based on the travel distances to incidents, assuming that the time taken to arrive at the incident location is the most significant factor in determining the overall intervention times. For large, complicated buildings, especially those requiring fire fighters to travel large distances either horizontally or vertically up stairs and with equipment, the travel time in a fire appliance to a specific address point may not constitute the most significant proportion of the total intervention time. It is important, therefore, to understand the overall fire brigade intervention time so the appropriate resources can be made available and to ensure that the most efficient operational response to an incident can be undertaken without unnecessary delays.

This chapter presents the analysis of New Zealand data required to populate the FBIM and that relevant to assessing fire service response characteristics within building designs.

7.2. NZFS Fleet and Hose Equipment

As an introduction to the NZFS fleet and equipment, the following section briefly discusses some of the main equipment and fleet used as standard throughout the NZFS.

7.2.1. NZFS Fleet

In the NZFS, fire engines or trucks are commonly referred to as fire appliances. There are six classifications of appliances within the NZFS operational response fleet classed as:

- Type 1 < 10,000 kg small pump – urban/rural;
- Type 2 < 12,000 kg medium pump – urban/rural;
- Type 3 < 14,000 kg heavy pump – urban;
- Type 4 > 14,000 kg heavy pump elevating monitor – urban;
- Type 5 > 14,000 kg aerial without a dedicated pump – urban;
- Type 6 > 14,000 kg heavy aerial – with full crew cab, tank supply, hose reels and dedicated pump.

Although each type of appliance has slightly different crew and equipment characteristics, it is not necessary to differentiate between these appliances when undertaking an FBIM analysis as NZFS procedures and polices ensure that the minimum number of staffing and equipment will be present and can be assumed as available when an appliance is in attendance at an incident. The only exception to this is for aerial appliances and the number of crew that will be present to operate the specific aerial appliance available within a specific fire area as discussed below in section 7.7. Further information on NZFS vehicles and their specific characteristics can be found on the NZFS website. Where necessary, the relevance of operational fleet to the FBIM is discussed in the following sections.

7.2.2. Hose Equipment

The NZFS uses a range of hoses that can be divided into the following main categories:

- feeder hose;
- delivery hose;
- suction hose.

7.2.2.1. Feeder Hose

Feeder hose is used to supply water from a pressurised water source such as a municipal supply accessed using a standpipe. Feeder hose used to supply a fire appliance is typically larger than delivery hose used to fight fires and is typically 90 mm (actually 89 mm) in diameter and 30 m in length to maximise flow capacity. A 25-m long, 70-mm diameter hose is also starting to be used as feeder hose on some appliances, typically in use with newer Type 1 and 2 volunteer appliances, and has replaced the conventional 90-mm feeder hose due to weight and handling advantages.

7.2.2.2. Delivery Hose

Low-pressure delivery hoses used to attack larger fires typically consist of a number of 70-mm hose with a final 25 m length of 45-mm diameter hose provided for manoeuvrability. The last section of hose, named the branch man's length, will typically be run out on the 'bite' to allow for the fire fighters to approach the fire from this location with up to 25 m worth of manoeuvrable hose. All NZFS lay flat hose are non-percolating and are specified to comply with BS 6391 (54).

One of the main differences identified between Australian fire brigades and NZFS equipment is the slight differences in the hose type, length and diameter and the couplings used. The FBIM provides data associated with the use of 90-mm, 65-mm and 38-mm diameter lay flat hose which is all 30 m in length and 3-m long rigid suction hose. This has implications for building designs and for FBIM analysis as the differences in hose lengths may need to be factored into an analysis of building design considering the effective reach of hoses. The most significant difference found to date is that between a typical Australian high-rise hose pack and an NZFS hose pack. Further information regarding the use of high-rise hose packs is discussed in Section 0; however, for comparison a standard high-rise pack in Australia consists of two 30-m lengths of 38 mm duraline hose providing a maximum of 60 m reach not including the reach of the water jet. The NZFS high-rise pack consists of one length of 70-mm hose and a single length of 45-mm hose for the branch man's length, providing for 50 m of effective reach. The differences between the use of these hoses, considering the difference in length versus hose diameter, is unlikely to impact on the deployment time considering both systems use only two hoses. However, for design purposes, the difference of 10 metres needs to be recognised as this is an operational limitation of the equipment used and compartment sizes and layout designs that are not inclusive of this limitation would be outside the reach of fire-fighters' capabilities.

There is no distinction between the types of couplings used and thus it is assumed that any difference between the use of different coupling types would be negligible. There are seven different coupling types used throughout Australia, excluding suction hose. These are identified within various Australian standards including Table E1 of the fire hydrant installations replicated below in Table 1. The NZFS uses 65-mm British Instantaneous Couplings (BIC) for lay flat hoses as shown in Figure 16 with Australian Storz hermaphrodite couplings.

Table 1 Types of fire hose couplings used within Australia

Types of fire hose couplings	
Type	Description
1	British instantaneous to BS 336
2	Storz hermaphrodite
3	64 mm × 4.88 mm pitch (2½ × 51/5 TPI)
4	64 mm × 5.08 mm pitch (2½ × 5 TPI) Whitworth form
5	63 mm × 8.47 mm pitch (2½ × 3 TPI)
6	Queensland round thread
7	SA round thread

Lay flat delivery hose is stored on an appliance in rolled coils, which require running out between specific locations or in pre-connected flaked arrangements, allowing the hose to be pulled straight out from the appliance direct to the required location. As BIC are classed as male and female couplings, they are stored so that they are rolled out from the appliance to the location of the fire holding and the hose rotated around the female coupling. Figure 16 shows the Storz hermaphrodite couplings and hose rolled in a 'Dutch' roll configuration allowing any coupling to be connected to another piece of waterway equipment with the same coupling.

Figure 16 NZFS BIC (left) and Australian Storz couplings (right)

High-pressure deliveries are carried on most fire appliances. Typically, two 60-m high-pressure hose reels are mounted on either side of the appliance to allow them to be taken quickly and directly from the appliance to the fire location. High-pressure deliveries have an internal diameter of approximately 25 mm and operate at a maximum working pressure of around 3500 kPa. For smaller fires and ones which can be accessed within the length of the reel, they allow a quicker attack on a fire as they are lighter and more manoeuvrable than using 70 mm/45 mm low-pressure deliveries. It should, however, be recognised that high-pressure deliveries need to be dragged from the appliance and along the ground which becomes difficult towards the end of the reel and around objects in some configurations.

Other types of hose, including specialist forestry and percolating hose, are carried on specific appliances. These are not discussed here further and are not incorporated into the FBIM as they are not typically used for urban fire fighting.

7.2.2.3. Suction Hose

Suction hose is used to draft water from open water sources or no elevated static supplies. Hard suction, as it is also known, comes in various sizes ranging from 100-mm to 150-mm internal diameter sizes and is typically 2.5 m in length. Normally four lengths are carried on a fire appliance allowing for a maximum reach of 10 m from the appliance inlet. The maximum lift determined by the appliance pump and length of suction hose together with the access arrangement normally restricts the ability and lift available for use of open water sources further than 6–7 m from the appliance inlet.

7.3. Data Collection Methods

The type of data required to populate the FBIM and to allow quantification of fire brigade intervention times across the broad spectrum of responses to fires that could occur is significant, and requires different types of methods to collect and analyse the different types of data sets. The data currently provided within the FBIM manual contains the following different types of data sets:

- times associated with the operation and notification delays of detection and suppression systems;
- processing times within emergency communication centres and times associated with notification of the relevant fire appliances;
- travel distances and response speeds associated with responding fire brigade appliances;
- times associated with individual fire ground tasks, from running hose to search and rescue activities including those associated with specialist fire appliances such as aerial appliances.

The collection of data presented herein has been established through a number of different methods including:

- analysing the latest statistical data available from the NZFS Intergraph Computer Aided Dispatch System (ICAD) over the period from July 2008 to June 2009;
- use of various software packages including the TransCAD Facility Location software tool and Google™Maps to provide information on fire appliance distances travelled to incidents;
- preparation and trialling of operational exercises to allow individual brigades to undertake exercises and record the times associated with specific operational tasks;
- undertaking specific large scale operational exercises including mock incidents within buildings;
- attendance at fire incidents and observing fire ground tasks;
- observing incidents on appliances at different fire stations in different locations;
- reviewing available video footage of fire incidents.

To compare and produce useable results from the data collected for use in the FBIM and a probabilistic analysis, the Palisade software package @Risk (55) was used to fit distributions to the data. The @Risk software ranks all the fitted distributions using a number of fit statistics allowing comparison and a measure of how well the distribution fits the input data. For each of the data sets collected, the fitted distributions and resultant functions were visually compared and consideration was given to the type of distribution function considered appropriate based on the @Risk calculated fit statistic and nature of the data collected. For the majority of the distributions proposed, the distribution that returned the lowest calculated fit statistic and therefore the best fit has been used, calculated using either chi-squared or Kolmogorov-Smirnov fit statistics.

This chapter presents the data that has been collected as part of this research and describes each of the methods in more detail with each set of data collected. The following sections provide information to support the FBIM based on the data entry tables given within the FBIM manual. For ease of reference, the following information has been provided in the same order as that given within the FBIM manual and reference is given to the appropriate FBIM chart and where data is proposed for use within an FBIM analysis it is provided in a similar format as given within the FBIM. Where data has not been collected to date, the existing Australian data has been re-evaluated using @Risk and the distributions found to best fit that data is discussed. Where considered relevant for use in the New Zealand context, the @Risk distributions from the original FBIM Australian data has been provided for use within a probabilistic analysis.

7.4. Activities Required for Fire Brigade Notification

The following sections relate to those activities required to occur before notification and dispatch of fire fighters can occur and consider the various methods available and necessary process times associated with each individual component.

7.4.1. Time Taken for Initial Brigade Notification

Table A within the FBIM presents times associated with an automatic suppression system operation with regards to the requirements of the Australian sprinkler standard. The FBIM provides a range of times and recommends using 180–360 seconds for a system complying with the Australian Standard AS 2118.1 and three times for ordinary hazard systems depending on the floor area of installation. These are given as 10, 20 and 50 seconds for installation areas of less than 1000 m^2, between 1000 and 2000 m^2 and above 2000 m^2, respectively.

In New Zealand, commercial automatic fire sprinkler systems are generally installed to comply with NZS 4541 (55) which provides no alarm response time requirements for sprinkler activation. Unlike other sprinkler systems designed to meet other international standards such as Factory Mutual and NFPA systems, NZS 4541 systems do not have an inspector's test cock at the furthest remote point in the system allowing for this specific value to be readily established. Typically, the majority of the sprinkler systems installed in New Zealand are classed as 'Type X' systems, which employ super-pressurised systems with no time-related specifications required. NZS 4541 does provide performance levels for signalling when 'Type Y' alarm systems are used; however, these are relatively rare and are generally only utilised where water supply pressures exceed 800 kPa. For 'Type Y' alarm systems, the standard requires that an alarm signal must be generated within 20 seconds of the alarm valve lifting (Clause 407.2.2.2(iv)). However, it is understood that this 20 seconds is taken from the time when the alarm valve lifts until the NZFS notification and evacuation sounders signals are sent. The standard does not provide any requirement for how long the time delay is from when the sprinkler head operates until the system drops enough pressure for the alarm valve to lift.

Factors that influence the alarm signalling time after sprinkler operation have been established to include:

- the system volume;
- super-pressurisation level;
- the amount of trapped air;
- sprinkler orifice size, reticulation routing and its height relative to the valve set;
- the number of heads that open;
- the actual system standing/design pressure;
- the performance and setting of the pressure switch.

This specific item has been discussed with a number of sprinkler experts and committee members involved in drafting the NZS 4541 standard who have all stated that this time period can be considerable and is likely to exceed 60 seconds for many systems(56)(57)(58). For some expansive systems, the NFPA five-minute requirement may not be (and are not) met, particularly when the system incorporates automatic jacking pumps. Because of the lack of data that exists for NZS 4541 systems and because of the level of variability that could impact on this response and signalling time, it is difficult to establish a time period or nominal value for an NZS 4541-compliant sprinkler system irrespective of basic design information such as the size of the building and area to be covered, for example. However, anecdotal evidence provided by persons well experienced in the testing and commissioning of various different types of sprinkler systems suggests values and ranges that would be considered appropriate given the range of variables that are known to affect this time. Based on the information supplied and the knowledge that systems such as NFPA 13 and Factory Mutual have performance standards for this time period, it is suggested that a range between 60 and 360 seconds be used for wet pipe sprinkler systems that comply with NZS 4541. For dry pipe systems complying with the same standard, a single time delay of 90 seconds has been advised as appropriate. For the purposes of the FBIM data, these values are given below in Table 2 and shown in Figure 17 as a uniform distribution for use within a probabilistic analysis.

Table 2 Proposed New Zealand data additions to FBIM Table A

Activity	Floor area of installation	Time (s)
NZS 4541 compliant system – Wet pipe system	n/a	60-360
NZS 4541 compliant system – Dry pipe system	n/a	90

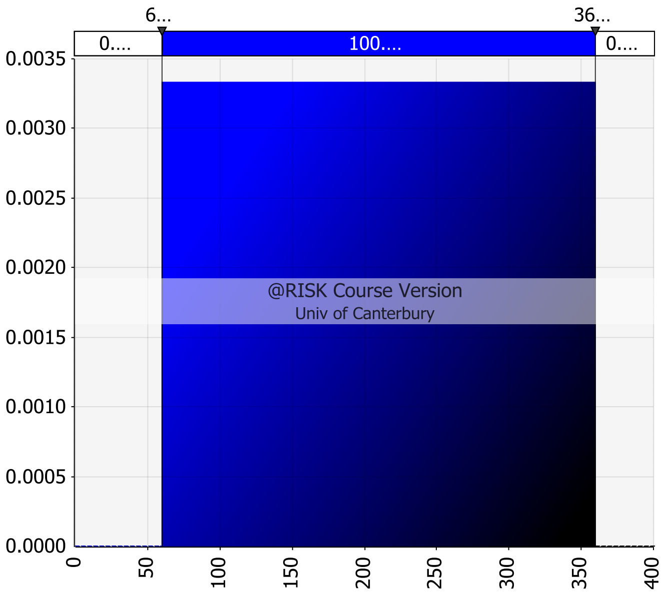


Figure 17 Proposed uniform distribution min 60 s, max 360 s of the time taken to depressurise an NZS 4541-compliant sprinkler system and activate the alarm

Until specific research into this aspect of sprinkler system operation is established for NZS 4541 compliant systems, a uniform distribution is considered appropriate to take into account the probability of the actual value falling within the proposed range. If the distribution is used within an FBIM analysis, a sensitivity analysis of the result should be undertaken to understand how sensitive the result is to this specific and other input variables. If it is found that this specific value is of significance to the output then additional analysis could be undertaken to further refine the confidence in the value used.

7.4.2. Times for Alarms/Fire Verification and any Notification Delays

FBIM Table B provides only a single value of 20 seconds for the *'time delay for alarm verification'* which is recommended to be incorporated for both detection and suppression systems. This verification period is incorporated into the time period given in Section 7.4.1 and does not need to be repeated for an NZS 4541 sprinkler system.

The New Zealand standard for fire detection and alarm systems in buildings NZS 4512 (59) provides maximum times for both system response to activations and alarm verification. Once a detector activation time has been calculated, NZS 4512 requires that the systems respond within a maximum time of 15 seconds. Once a device has activated, the standard then requires verification of activation. Unless an analogue detection algorithm is used within the system to minimise spurious alarms, the standard requires a smoke detector circuit to activate twice before a fire alarm signal is generated. The standard specifies that this verification period cannot take longer than 15 seconds, allowing for a combined maximum delay of 30 seconds for a detection system installed in accordance with this standard.

Depending on the design of the detection system and not accounting for any specifically designed systems that may incorporate additional 'double knock' type verification delays or 'managed' time delays which are common in New Zealand, it would be conservative to allow for a 30-second verification-delay time period without further investigation or research into this delay period.

FBIM Table B also provides for four other time steps that are associated with verifying a fire when no automatic suppression system or detection systems are installed. The FBIM recommends that these times be supplied by designers as they will be specific to the project. Should an automatic detection system not be installed, it is difficult to establish a time that can be confidently relied upon to alert the fire service and for this reason it is not recommended to undertake designs that do not incorporate a reliable means of notification unless these can be appropriately substantiated.

The following time is therefore recommended to be included into the FBIM Table B.

Table 3 Proposed New Zealand data additions to FBIM Table B

Activity	Time (s)
Time delay for heat and smoke detection response and verification, NZS 4512 compliant system	30

7.4.3. Times for Receipt of Information and Dispatch

FBIM tables C and D provide various times for the receipt of information and dispatch components, depending on the specific nature of the emergency call or way in which the relevant fire service is notified of an incident. In Australia, the different brigades use a number of different systems which vary from state to state and can also vary according to whether the incident occurs within a rural or urban area. New Zealand uses a fully electronic Computer Aided Dispatch (CAD) system for which the FBIM manual suggests removing all additional notification delays. However, this project has identified a time component associated with the dispatch system used within New Zealand and therefore proposes in the next section a distribution associated with this dispatch time component.

It is also worth recognising that the use of centralised communication systems and those shared with the other emergency services in New Zealand reduces the methods in which the NZFS would be potentially notified of an incident. Other methods might include members of the public calling a local fire station, either by phone or by person, for example. In these circumstances, NZFS policy requires that the call be redirected and placed through the communication centres so that the appropriate responses can be dispatched following the correct and standardised procedures. The times associated with emergency 111 calls, notifications provided by private or intermediate monitoring companies and those associated with dispatch using the CAD system are addressed in further detail in section 7.5.3. For purposes of the FBIM manual, the methods of communication and dispatch of NZFS resources using a fully electronic CAD system is simplified and removes the need to use FBIM chart 2, steps 5, 8 and 9.

7.5. Response Times

7.5.1. Introduction

This section provides the data required for a time component to assess the time taken for a fire appliance to arrive at a specific location from the time the NZFS first becomes notified of an incident.

This research used the latest data available for approximately 6,410 fires in structures throughout New Zealand attended by the NZFS over the period from July 2008 to June 2009 (60). Comparisons between response times within urban and rural fire districts are presented and comparisons between the main New Zealand cities and their central business districts and outer suburbs are compared. Distributions have been fitted to the data using the software package @Risk (55).

7.5.2. Historical Background to Fire Service Response Times

Historically, fire-station locations were based on the limitations of the equipment and appliances and the time taken to get to the location of the fire. Many fire-station locations around the world including some surviving today were based on the ability of fire horses to haul equipment and steamers in five minutes (61).

Modern day international standards of response coverage can differ significantly. In Ontario Canada (62), standards of coverage are specifically noted to be primarily influenced by distance and travel time for selecting a fire station site. Examples given include requirements for the fire department to reach the downtown core in 3 minutes, the urban boundaries in 5 minutes, 75% of the rural area in 8 minutes and the remainder in 10 minutes. Figure 18 illustrates the differences between using the traditional circle drawn on a map and the more accurate method of a diamond to account for right-angled roads.

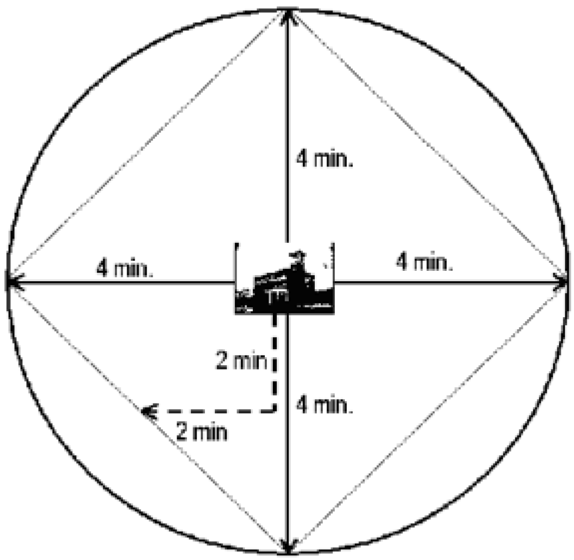


Figure 18 Canadian method to illustrate the differences between a circle and a diamond from a fire station that has used 4 minutes as the desired initial response time

In the 1970s, Kolesar and Walker (63) studied the relationship between time and distances of 2000 incidents attended by 15 units within New York City at different times of the day. This study found that for short distances travel time increased with the square root of the distance and that for long travel distances the travel time increased linearly. The study also concluded that travel times differed between the times of day but these were relatively small differences and could be ignored for planning purposes. The travel times found between different parts of the city were also so small that the average velocity that was obtained was almost constant throughout all parts of the city. Whilst this study was based on data from the 1970s, more recent studies in other parts of the world have used these findings and concluded that the relationship is also true for many other cities (45; 42).

NFPA 1710 (64) provides standard response criteria and expectations for the deployment of fire brigade resources including, amongst other criteria, that the first arriving fire appliance or ‘Initial Arriving Company’ shall arrive within 240 seconds to 90% of the incidents. The criteria established within NFPA 1710 is of particular interest given that it is being informed by research (65) that is being undertaken in an attempt to quantify fire brigade intervention which shares similarities to that of the FBIM.

In the UK, the national standards of fire cover comprised four categories of risk (A, B, C and D) and specified a time of response for each risk type. A further category ‘Remote Rural’ exists for which no specific response is laid down and 'best efforts', often relying on volunteer assistance, are made. The standards originated before World War II and were implemented in 1947; they were subsequently reviewed but not significantly changed (66).

Essentially, the standards originally required the first arriving appliances to be at the scene in 5, 8, 10 and 20 minutes, respectively, for each risk (4). However, the introduction of Integrated Risk Management Plans (IRMPs) in 2004 (67) removed the national standards of fire cover and required individual county brigades to undertake an Emergency Planning Process to define response times. IRMPs require brigades to incorporate risk assessments, response planning, resource allocation and the assessment of effectiveness of the resources available when deciding on resource allocation.

In New Zealand, the NZFS stipulates that response times for fire incidents inside fire districts be monitored for performance against the national service delivery guidelines of:

- 7 minutes, 30 seconds 90% of the time for permanently manned stations, and
- 10 minutes 90% of the time for volunteer stations.

7.5.3. New Zealand Fire Service Response Times

The NZFS collects response time data using time stamping by an electronic dispatch system based on radio-transmitted codes. NZFS response starts automatically at the moment an emergency call signal arrives at the Fire Service communication centre and includes time to answer the call, time to verify the location of the incident, time to alert fire stations, time for crew to dress and leave the fire station and time to travel and reach the incident location. Fire appliances use a touch-screen mobile status unit as shown in Figure 19, allowing for operators to provide confirmation of appliance status (such as arrival at an incident) instantly and with visual verification that the transmission has been made. These units reduce the incidents of accidental operation and allow for accurate time/date stamping of specific actions providing that operators input the status at the correct times.

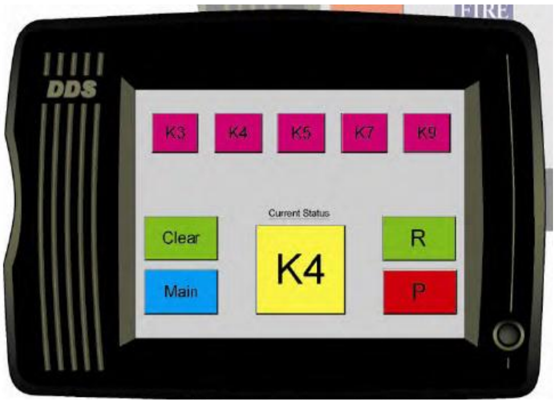


Figure 19 Typical NZFS mobile status unit

From the NZFS Incident Data, the following times for every structure fire have been obtained:

- incident date/time;
- confirmed time;
- station alert time;
- enroute time;
- arrival time.

From each of these times, the distributions have been analysed for incorporation within the FBIM for the following data requirements:

Table C – times for receipt of information;
Table D – times for dispatch;
Table E – times for fire-fighter response.

Whilst certain mandatory data fields are required to be collected for structure fires, the NZFS Incident Data does not require that the distances travelled to the incident be recorded. Whilst data on reported distances travelled is collected, this is not accurate and cannot be used to calculate an average travel speed for each incident attended. To obtain the travel distances to every incident attended over the period from July 2008 to June 2009, the TransCAD Facility Location software tool (68) was used to calculate the shortest route possible between the first arriving fire appliance from the nearest fire station and the incident location. This allows for analysis of the average travel speed of the first arriving fire appliance and provides data to populate Table F – speed data for brigade travel – of the FBIM.

The NZFS is comprised of eight different regions which includes 345 urban fire districts with around 436 stations. Because of the varied nature of the New Zealand landscape, this analysis considered a number of different factors to identify the need to establish different response times for different areas. The analysis considered specifically the difference in response time between UFD and RFD. The data was obtained from the main city centres including Auckland, Wellington and Christchurch and from any differences found between the central business districts (CBD) of each of these cities and their outer suburbs. For the CBD and outer suburb analysis, the busiest fire appliances for each area (those that attended most structure fires during the July 2008 to June 2009 period) were isolated from the data and the respective response times specifically assessed.

7.5.4. Times for Receipt of Information

Once an NZFS communications centre receives information that a fire incident has occurred, either by direct communication from an automatic alarm system or from an emergency 111 phone call, the time is logged until the incident location has been confirmed. The NZFS incident data differentiates between 13 different types of alarm methods used to call the NZFS. Table 4 indicates the alarm methods used to call the NZFS as recorded from all of the 2007–2008 incident data assessed and the number and percentage of times those alarm methods notified the NZFS of the structure fires.

Table 4 Alarm methods used to call the NZFS for all structure fires

Alarm methods	Number of incidents	Percentage of incidents
111 Telephone call	5487	86
Automatic private fire alarm (PFA) call	270	4
Manual PFA call (operation of a manual call point)	224	3
111 Telephone call made from a private monitoring company	109	2
Police call	103	2
Exchange phone call	56	1
Sprinkler PFA call	48	1
Running call	42	1
Ambulance call	34	1
Vehicle call on radio	21	0
Other PFA call	13	0
Airport call	1	0
111 from security company/agent	1	0

Table 5 shows the same alarm methods use to notify the NZFS but with the data isolated for the six appliances specifically assessed within the main cities. As is to be expected, the percentage of incidents notified from private fire alarms (PFA) is greater, especially for smoke detection systems, as there is a greater proportion of high-rise buildings that have such systems which places less reliance on emergency 111 phone calls.

Table 5 Alarm methods used to call the NZFS in main cities

Alarm methods	Number of incidents	Percentage of incidents	Percentage change from whole country
111 Telephone call	305	70	−16
Automatic PFA call	51	12	7
Manual PFA call (operation of a manual call point)	39	9	5
111 Telephone call made from a private monitoring company	12	3	1
Police call	9	2	0
Exchange phone call	7	2	1
Sprinkler PFA call	4	1	0
Running call	4	1	0
Ambulance call	3	1	0
Vehicle call on radio	1	0	0
Other PFA call	1	0	0
Airport call	0	0	0
111 from security company/agent	0	0	0

For the purposes of FBIM data and assessment of notification methods, the times of most interest include those times taken to receive and verify the location of fire incidents from the receipt of emergency 111 calls from both members of the public (including building occupants and passers-by) and security companies notified by a non-brigade-calling fire-alarm system and from PFAs (either from operation of manual call points, automatic smoke detection or sprinkler systems).

The FBIM provides two values for the times taken to receive and confirm the incident location. These are given in Table C, section 7 and are not accompanied by any statistical distributions. This table is replicated below in Table 6 and provides values for the times expected for an emergency call centre operator to receive and take down the information and for an alternative option.

Table 6 FBIM Table C times for receipt of information

Activity	Time (s)
Time to receive and take down verbal information	60
Time for alternative option to be received and understood	to be advised

The NZFS operates using a fully electronic Computer Aided Dispatch (CAD) system. The time taken to receive and confirm the location of the incident and specific building location is recorded within the incident database as between zero and one second. As this is instant, this time period can be considered as zero within any analysis. The times taken for the CAD system to dispatch the specific fire appliances that are available to attend and are closest to the fire are considered in the next section.

Times required to be included within any analysis for where a PFA is not provided in the building include emergency 111 telephone calls made from either the public or from private monitoring companies if the building is provided with an alarm system that notifies a private monitoring company of a fire. Where buildings are not provided with a direct connection to the NZFS, the time taken to verify the location of the fire from receipt of a telephone call is variable and will depend on a number of factors including:

- the quality and clarity of the information provided by the caller;
- availability of emergency call centre staff;
- training and competency of emergency call centre staff.

If the alarm system within the building is being monitored by a private monitoring company, details of the agreement by which the monitoring company calls the NZFS will need to be ascertained as any additional delays in fire verification undertaken by the company before notifying the NZFS are not included in this analysis.

Of the 5,487 incidents notified to the NZFS by emergency 111 telephone calls, 17 data sets (0.02%) were removed as they had taken significantly longer than 200 seconds to verify the location of the incident. These were discounted to prevent the distributions from being skewed. In one case, a time in excess of 10 minutes was recorded, indicating a possible error in the data associated with these 17 data sets. Figure 20 shows the input data and the fitted lognormal distribution for the incidents notified to the NZFS by members of the public.

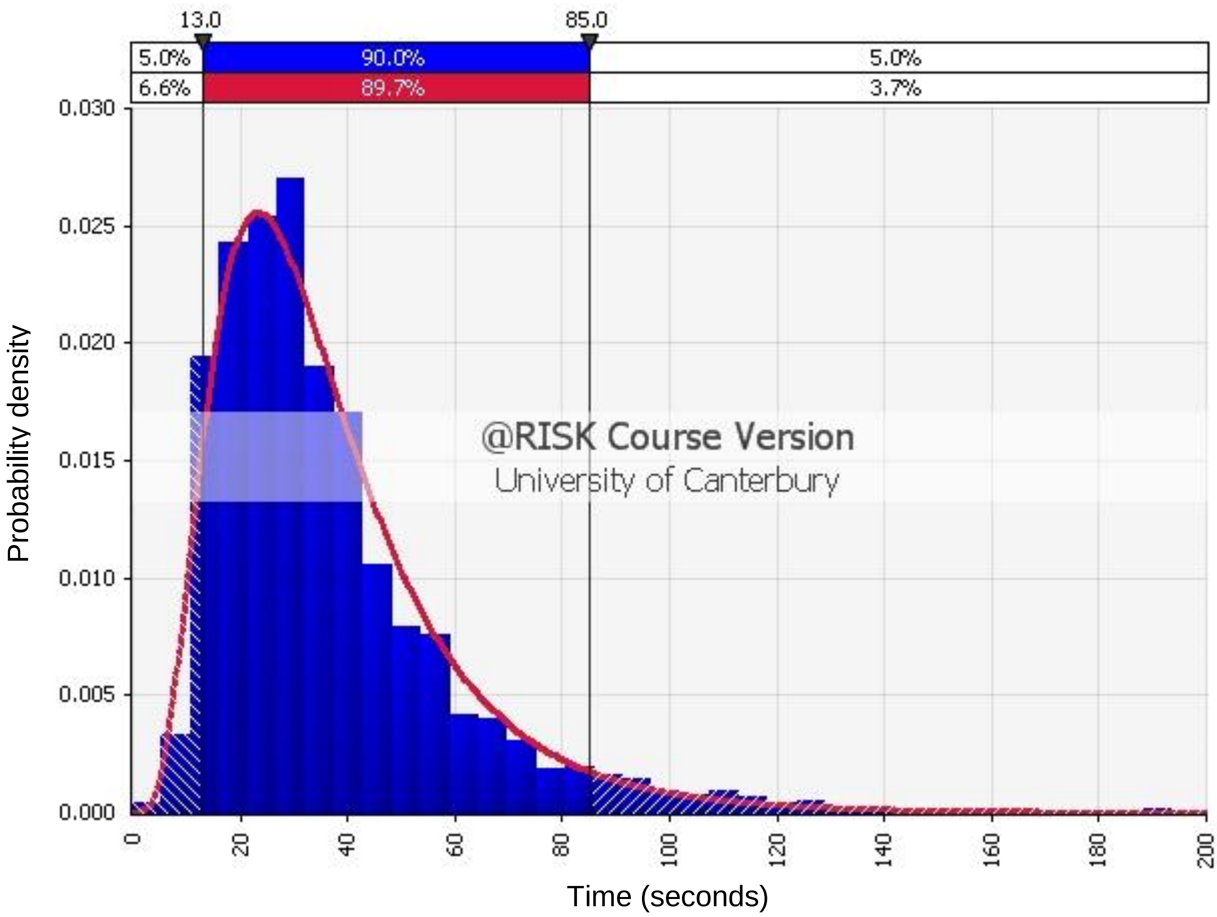


Figure 20 Fitted lognormal distribution - μ=39, σ=22.3, *Shift* -2.2 to incidents notified to the NZFS by emergency 111 telephone calls

Incidents notified to the NZFS by emergency 111 telephone calls made by private monitoring companies are shown below in Figure 21. For the 109 records, a lognormal distribution fits the data set well with no data sets removed. Only two incidents in this data set took over 200 seconds to verify the location of the incident; these have an insignificant impact on the fitted distribution and have therefore not been discounted from this distribution. These results are reported in Table 7 below and would replace those from the FBIM provided in Table 6.

For notification times associated with the receipt and confirmation of any incident locations requiring an emergency 111 telephone call, a lognormal distribution for the following types of notifications are recommended:

Table 7 Proposed New Zealand data additions to FBIM Table C

Location of incident (seconds)	μ	σ	Risk shift	Sample size
Automatic PFA (instant)	-	-	-	542
Emergency 111 telephone calls	39	22	−2	5470
111 from private monitoring company	35	34	16	109

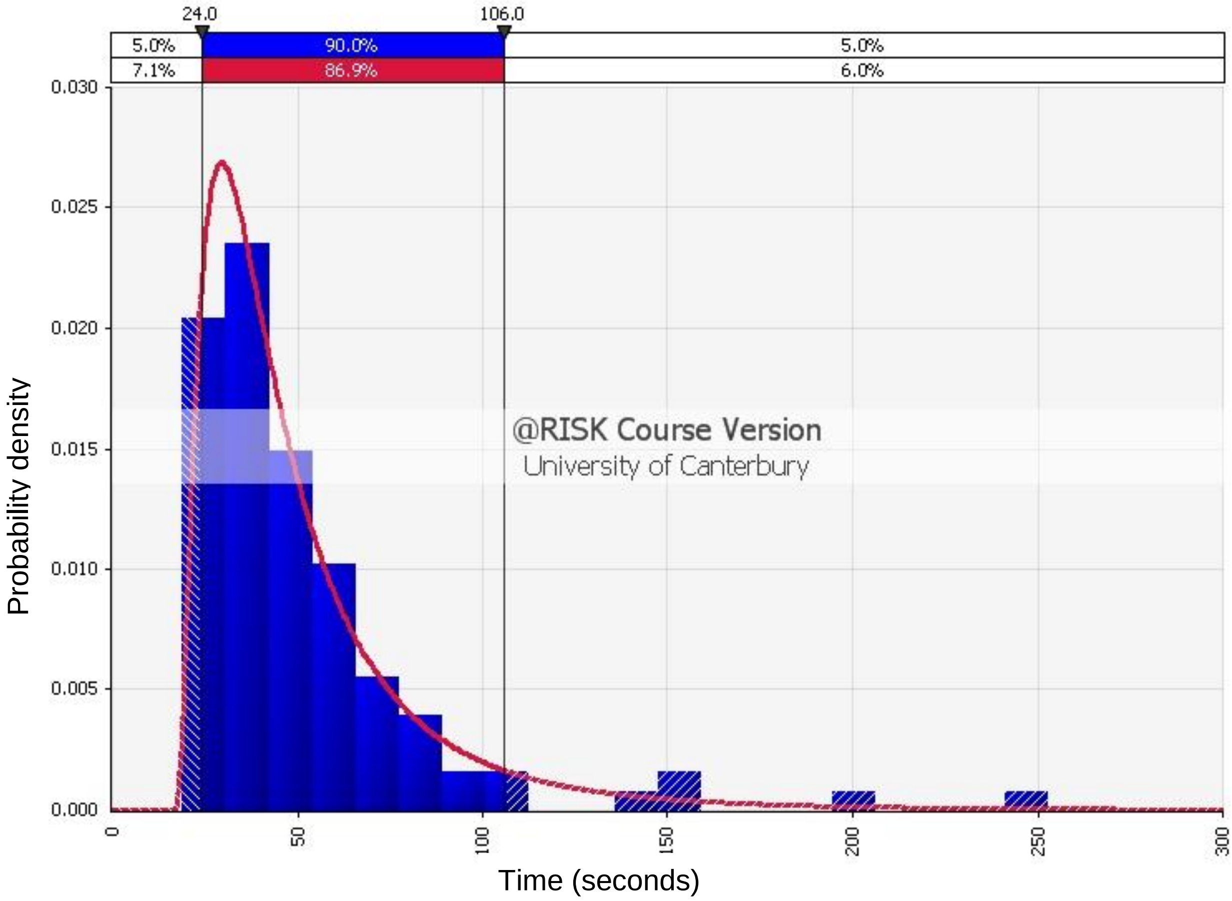


Figure 21 Fitted lognormal distribution μ=35.4, σ=34.2, *Shift* 16.3 to incidents notified to the NZFS from private monitoring company

7.5.5. Times for Dispatch

For incidents in UFD, 99% of fire appliances were dispatched by the CAD system in under 200 seconds. Times greater than 200 seconds were removed from any analysis to prevent the distribution from being skewed. Again, a small number of data sets indicated a possible data entry error with one data point exceeding 23 minutes taken to dispatch an appliance.

For incidents in the RFD, dispatch times slightly increased with a smaller frequency of values occurring below 10 seconds. While a number of values above 200 seconds were found, these did not significantly alter the fitted distribution compared with that found within the UFD.

Relatively short values are thought to be a consequence of fewer available resources within the location relative to the incident and a consequence of there being less choice and a higher chance of the closest appliances being available allowing for a quick and simple decision. In UFD, and especially in areas served by many fire stations and appliances, the CAD system must decide which appliances are closest to the incident and also which are available at the time of the incident. This choice of appliance becomes increasingly difficult and more complex the greater the number of appliances relative to the incident in question and if other incidents are occurring simultaneously or if appliances are unavailable.

The FBIM provides three values for the fire-fighter response times given in Table D, section 7 but provides no statistical distribution for these times. This table is replicated below in Table 8 and provides three time values and a user-specified value dependent on the system used by the agency responsible for dispatching fire-fighting resources. As the NZFS operates a single CAD system throughout the country only a single specified value is required.

Table 8 FBIM Table D times for dispatch

Times for dispatch	**Time (s)**
Special dispatch time to be assessed	to be advised
Time to relay dispatch information by fully electronic CAD system	0
Time to relay information by part manual CAD system	15
Time to relay dispatch information by phone or radio	30

As shown above, the FBIM assumes that for a fully electronic CAD system the time to dispatch resources should be taken as zero. However, in New Zealand data suggests that this is not the case and that a time distribution needs to be considered. This difference is likely to be due to the difference in data collection methods used to capture the data. The FBIM data is partly sourced from the Australian Incident Reporting System, refer section 4 of the FBIM manual (5 p. 34). Figure 22 shows the distributions for dispatch times in UFD and RFD with a fitted lognormal distribution. The distributions relate to 5238 records for the UFD and 716 records for dispatch times in RFD. The dispatch times were also isolated for the incidents that occurred within the main cities and again no significant distinction was found between the times. As such, all data sets have been assessed and the fitted lognormal distribution (μ=26.8, σ=14.6, Shift(−0.85)) representing the dispatch times for all incidents for the 2008–2009 period are recommended for use.

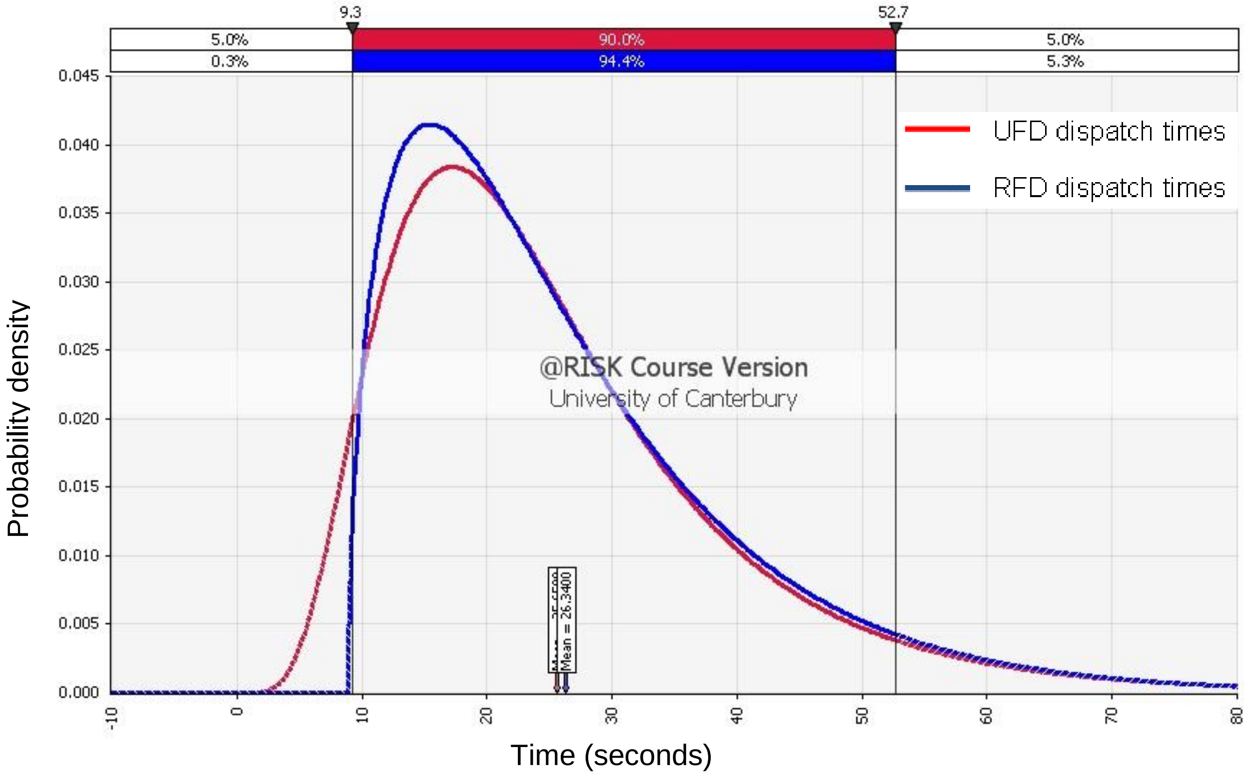


Figure 22 Fitted lognormal distribution for dispatch times in urban and rural fire districts

For times associated with dispatching of the responding appliances a lognormal distribution is recommended as follows:

Table 9 Proposed New Zealand data additions to FBIM Table D

Time for dispatch (s)	**μ**	**σ**	**Risk shift**	**Sample size**
Fully electronic CAD system	26.8	14.6	−0.85	6031

7.5.6. Times for Fire-Fighter Response

Once the fire station has been notified or 'turned out' to an incident, fire fighters need to assimilate the information provided and dress in structural fire-fighting clothing before mounting the fire appliance and leaving. The time taken for fire fighters to respond and leave for the incident can depend on the other activities being undertaken at the time of the incident call. Fire fighters undertake many duties other than responding to fire calls, such as fitness training and public fire safety work amongst other tasks. Also, should the incident occur at night, fire fighters may be asleep at the time of notification. These different duties and conditions incur different response delays and need to be factored into the overall response times.

Volunteer fire fighters may also have to respond to the fire station from their place of work or home and NZFS procedures require that a fire appliance cannot respond to an incident unless the appliance is appropriately manned and provided with the appropriate number of fire fighters to attend an incident safely. Before an appliance can be dispatched, four fire fighters are required to staff an appliance. For any design it needs to be established whether the incident will occur in a volunteer or career fire fighters’ first response area, as this may incorporate additional delays and uncertainties with responding fire crews that could be detrimental to the safety of the attending fire crews or ability of the responding fire fighters to undertake their statutory functions.

NZFS data indicates that approximately 1300 of the incidents analysed here recorded fire-fighter response times of less than 60 seconds and that 3000 incidents were responded to in less than 90 seconds. 200 incidents indicated times of less than 10 seconds indicating that either the fire fighters were in the appliance at the time of the call or there are anomalies in the data. Personal experience would indicate that it is not possible to attain response times of much less than 60 seconds unless fire fighters are already on the fire appliance or in situations such as training exercises that permit them to mount the appliance and leave almost immediately.

In some areas, the NZFS operates composite fire stations where full-time fire fighters share a station backed up by a secondary appliance manned by volunteer fire fighters. Also, some locations that are served by volunteer stations may also receive responses by fire appliances manned by full-time staff. In these cases where the response times of volunteer appliances result in long attendance times, confirmation should be made as to whether other appliances including responses from career fire fighters may be made from stations further afield in shorter times. Such a response would be similar to that where the fire and closest appliance to an incident is already committed to another task and therefore the first responded appliance may not be the closest located geographically to the incident location.

As the NZFS will dispatch more than one appliance to any confirmed structure fire, it is possible that the closest situated fire appliance may not be the first arriving appliance. Of the 6,410 structures fires assessed, the first arriving appliance at the incident in 656 or 10% of all calls was not from the closest situated fire station. In UFD, the first arriving appliance was from a fire station located further from the incident in 574 or 10.8% of the incidents. Therefore, where the calculated response times for responding appliances are excessively long, the attendance and arrival of multiple appliances from different locations can be assessed to provide further assurance of a response time for any appliance that would likely be dispatched. This can then be taken into account when assessing the tasks and manpower required at the event. The FBIM provides three values for the fire-fighter response times given in Table E, section 7 but provides no statistical distribution for these times. This table is replicated below in Table 10 and provides three time values; the first of 480 seconds representative of a volunteer response from fire fighters not based at the fire station full time which therefore includes travel time to the fire station, a second time of 90 seconds being the expected time for a fire fighter based at a fire station which would include response times from sleeping and a third time of 60 seconds to allow fire fighters to make up equipment assuming that they have been training and/or are around the appliance etc.

Table 10 FBIM Table E time for fire-fighter response

Time for fire-fighter response	**Time (s)**
Time to travel to fire station, dress, assemble, assimilate information and leave station	480
Time to dress, assimilate information and depart	90
Time to make up and become mobile	60

To take into account the differences between volunteer and career fire fighters, the NZFS data was again split into UFD and RFD times to compare the differences in response times and was also specifically assessed for the appliances situated in the three major cites (CBD and outer suburbs). Figure 23 shows the fitted distributions for the response times for the UFD, RFD and CBD and suburban appliances. A log logistic distribution described each of the responses best.

The faster responses occurred in the order expected with 95% of the responses for the main cities occurring within 123 seconds compared with 271 seconds for all the UFD appliances and 459 seconds for the RFD appliances. The mean responses times of 77, 113 and 224, respectively, and the shape of the associated distributions indicate the expected response times from career fire fighters compared with those that can be expected from volunteers.

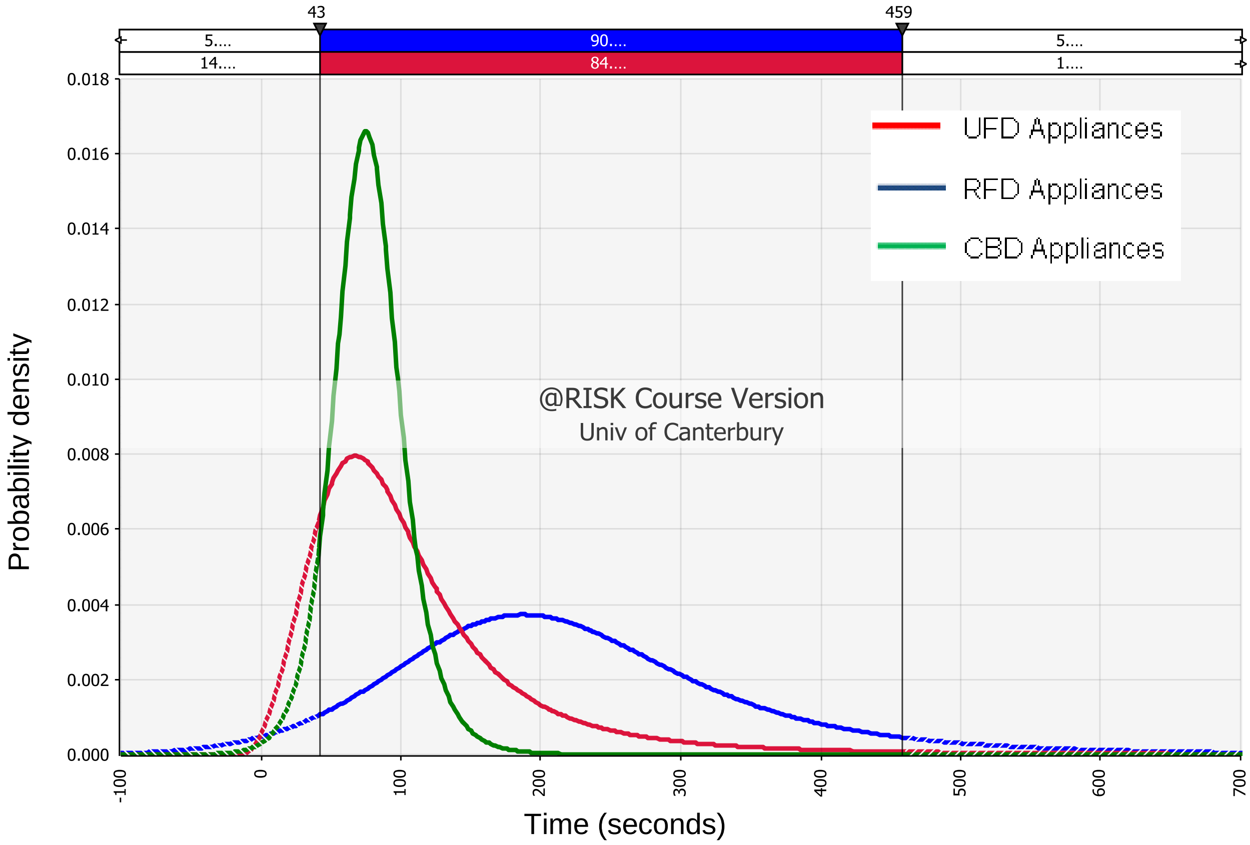


Figure 23 Fitted log logistic distributions for fire-fighter response times within the UFD: Γ=-12.7, β=103, α=2.9, RFD: Γ=-266, β=473, α=6.9 and CBD: Γ=-308.3, β=384.7, α=25.5

Table 11 Proposed New Zealand data additions to FBIM Table E (secs)

Location of incident	**Γ**	**β**	**α**	**Sample size**
Inside UFD	−12.7	103	2.9	5308
Inside RFD	−266	473	6.9	817
CBD	−308.3	384.7	25.5	421

7.5.7. Speed Data for Brigade Travel

The average travel speed that a fire appliance can obtain to reach the fire incident depends on a number of factors. Such factors include:

- travel distance from the location of the fire station to the incident;
- road type
  - CBD roads, state highway, motorway conditions, rural open roads
  - street arrangement including number and types of intersections;
- weather conditions
  - dry, wet, snow and ice;
- traffic conditions
  - peak rush hour traffic
  - congested traffic due to specific events
  - time of the day or night;
- type of appliance
  - pump, aerial appliance, age, weight;
- experience of driver
  - training
  - ability
  - choice of route.

Tommasson et al. (45) and Yung (69) considered the factors affecting the response time of fire appliances and considered the most important factors to be the distance travelled to the incident. The average travel speed obtainable however was found to vary significantly, with actual incident experience as reported in Chapter 8 indicating that average speeds found ranged from 20 km/h on city centre streets over short distances to as high as 70 km/h over longer distances using the motorway system. For comparable distances, average speeds were found to vary by as much as 20 km/h.

The data obtained was checked for anomalies; any negative response times (20 out of the 6,410 data entries, which can occur due to data entry errors) were excluded as were any response times that appeared to be excessively long (typically over 60 minutes, of which there were three). It is noted that a very small number of response times can exceed 60 minutes, particularly in remote rural areas or fires on remote islands without fire stations, such values were excluded from the analysis on the grounds that they can be due to data entry errors and they will unreasonably skew the analyses. Analysis of fire brigade intervention in remote locations would also be considered to be outside of the scope of the

FBIM and special consideration would be required if attempting to undertake a fire brigade intervention assessment for such locations. Also, spurious data entries that returned anomalies between the data points were removed, leaving 6,125 data sets available for analysis. These included travel speeds that were either below 0 km/h or well in excess of 100 km/h. 100 km/h was considered an appropriate bounding speed used for this analysis as this was witnessed to be the maximum approximate travel speed that an appliance could obtain on a flat, non-congested motorway and is the maximum safe allowed speed of most appliances under NZFS policy.

7.5.8. Urban and Rural Fire District Response Speeds

Of the 6,125 structure fires over the period from July 2008 to June 2009, 5,309 occurred within the UFD and 817 within the RFD. The distance for each incident calculated using the TransCAD software (68) divided by times taken for the appliances to travel to the incident provides the calculation of the average appliance speed to each incident. These times and distances are shown in Figure 24 below and indicate the positive correlation that would be expected between distance and the travel time.

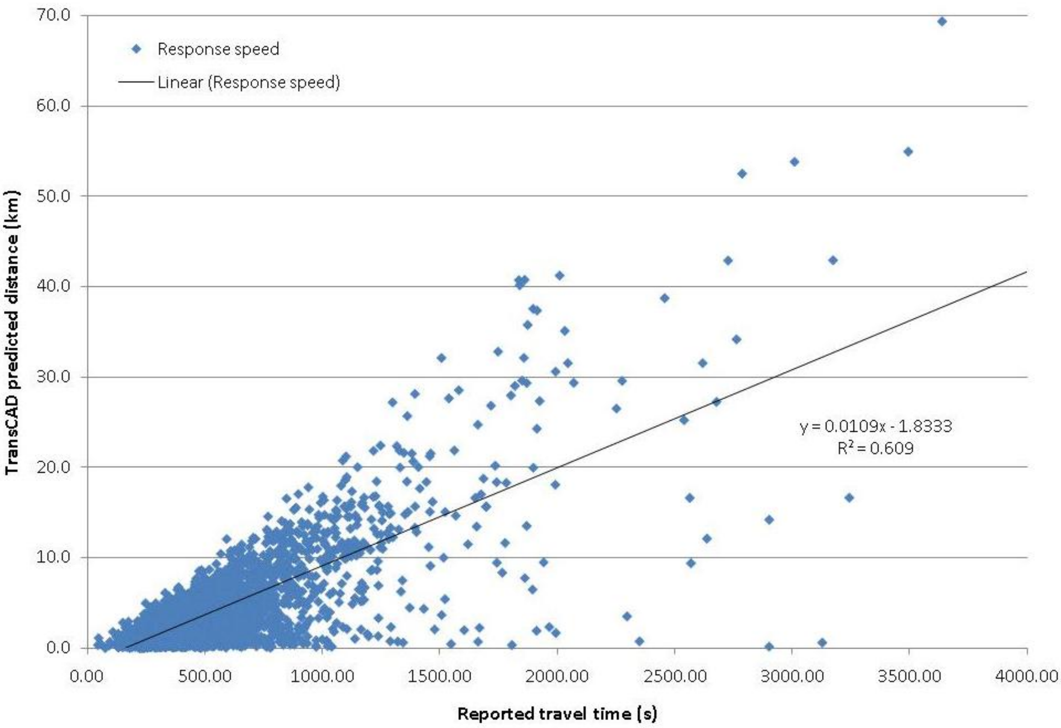


Figure 24 TransCAD predicted distances versus reported travel distances to 6,125 structure fires over the period from July 2008 to June 2009

Figure 25 below shows the fitted distributions to the data. A normal distribution described each data set well with the data set truncated to return minimum travel speeds of 0 and 100 km/h, respectively. It is recognised that use of a travel speed of 0 km/h within an analysis will return an infinite travel time. However, for the purposes of a probabilistic analysis this would occur in only a minimal number of iterations and could be used to acknowledge breakdowns and other situations that would prevent an appliance reaching the incident, as does occur and is reflected in the statistics.

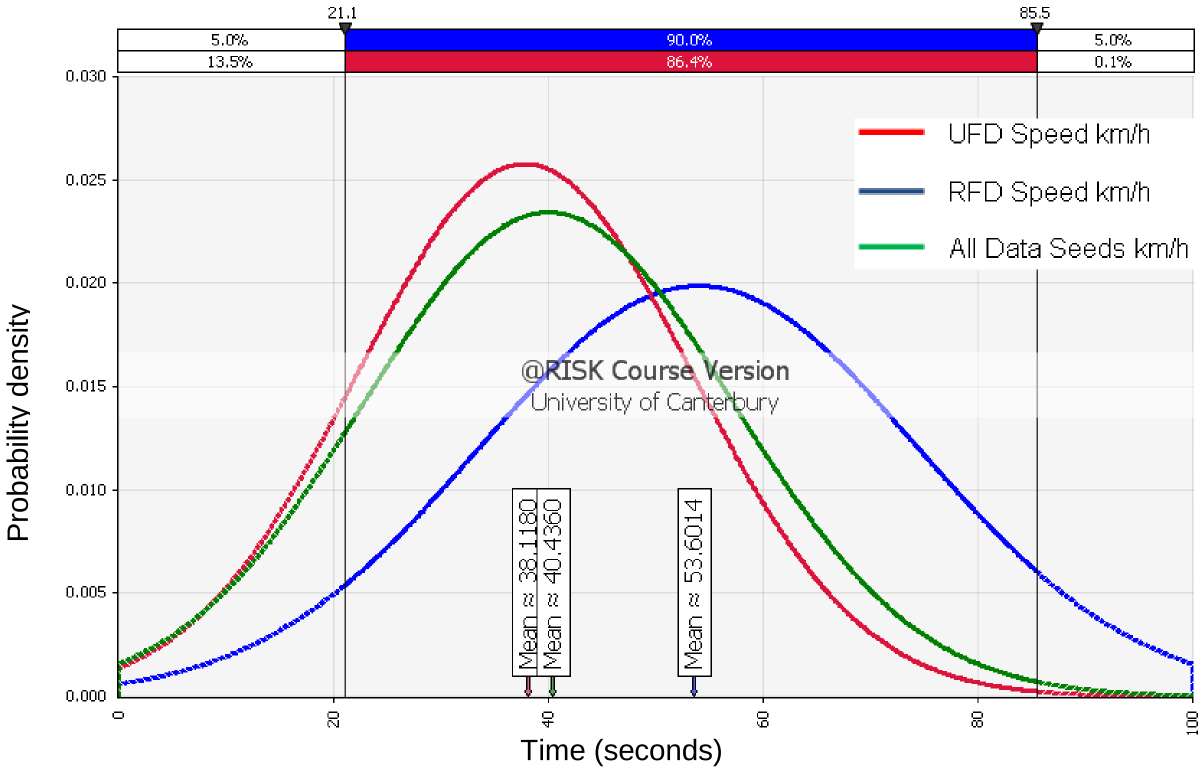


Figure 25 Fitted normal distributions of urban μ=38, σ=15.6 and rural fire districts μ=54, σ=20.4 response speeds compared with all the data sets in km/h

The average response speeds were found to be higher within the RFD by 13 km/h compared with those found within the UFD. This is to be expected given the congestion and slower road speeds found within the UFD. The travel distances considered for each incident are also of interest given the different speeds found between the urban and rural areas. These are reported below in Table 12.

Table 12 Reported incident travel distances for urban and rural fire districts

Travel distances (km)	Minimum	Maximum	Average
Urban fire district	0.01	11.9	2.2
Rural fire district	0.03	69.4	9.11

As would be expected given the greater density of fire appliances in urban areas, the incident travel distances within the UFD are significantly shorter than those travelled in the RFD. As would also be expected, higher average speeds are found over longer distances due to longer roads and less angled turns.

7.5.9. CBD Fire Appliance Response Speeds

Average response speeds for the busiest CBD appliances within Auckland (79 records), Wellington (85 records) and Christchurch (118 records) were compared. Figure 26 below shows the fitted distributions again using a normal distribution with the data set truncated to return minimum travel speeds of 0 and 100 km/h, respectively.

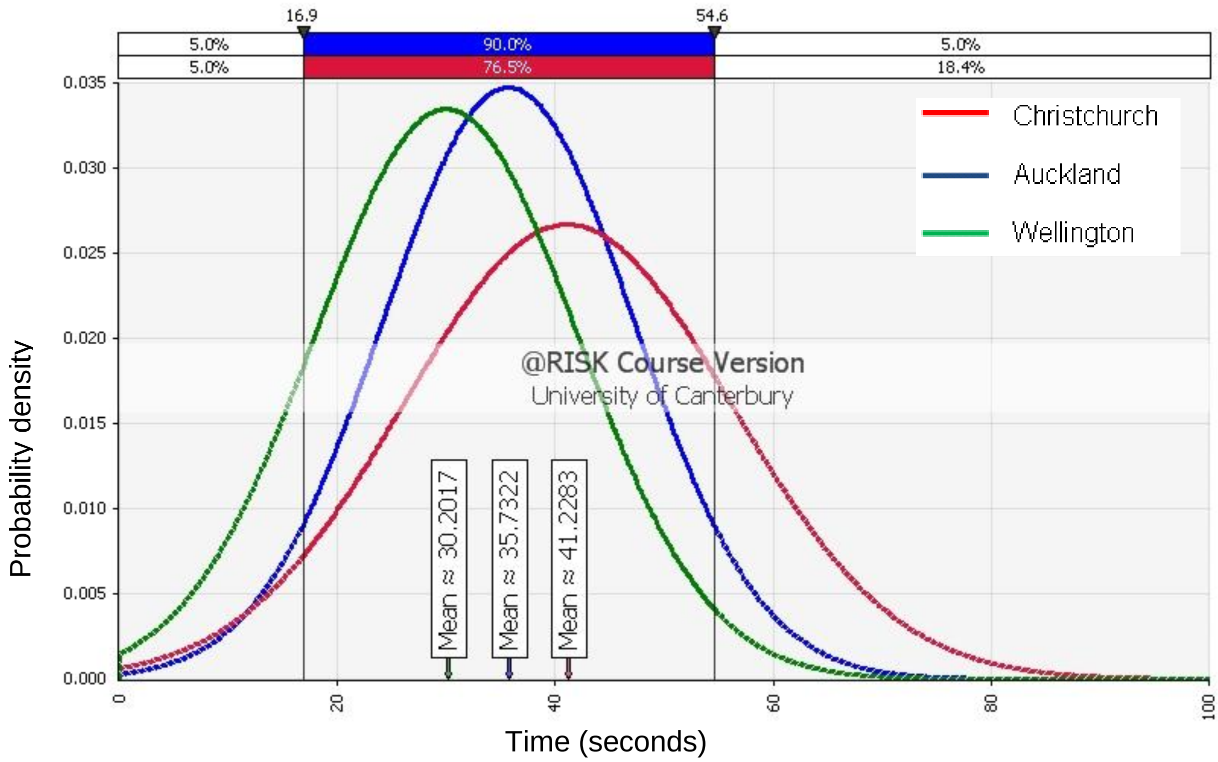


Figure 26 Fitted normal distributions of CBD fire appliance response speeds in Auckland μ=35.7, σ=11.5, Wellington μ=30.2, σ=12 and Christchurch μ=41.2, σ=14.9 in km/h

Considering the geography, population and density of each of the cities, the average travel speeds and their rank order are not unexpected. This is further discussed in the following section.

7.5.10. CBD and Suburban Fire Appliance Response Speeds

Average response speeds for the busiest CBD appliances have also been compared with each of the main suburbs within the three cities. For each of the outer suburbs specific representative fire appliances with a representative number of data sets were used including in Auckland (42 records), Wellington (46 records) and Christchurch (45 records). The number of structure fires attended for the first-arriving appliances in the suburbs is approximately half the number of first-arriving appliances in the respective CBDs. Figure 27 shows the fitted distributions, again using a normal distribution, with the data set truncated to return maximum and minimum travel speeds of 0 and 100 km/h respectively.

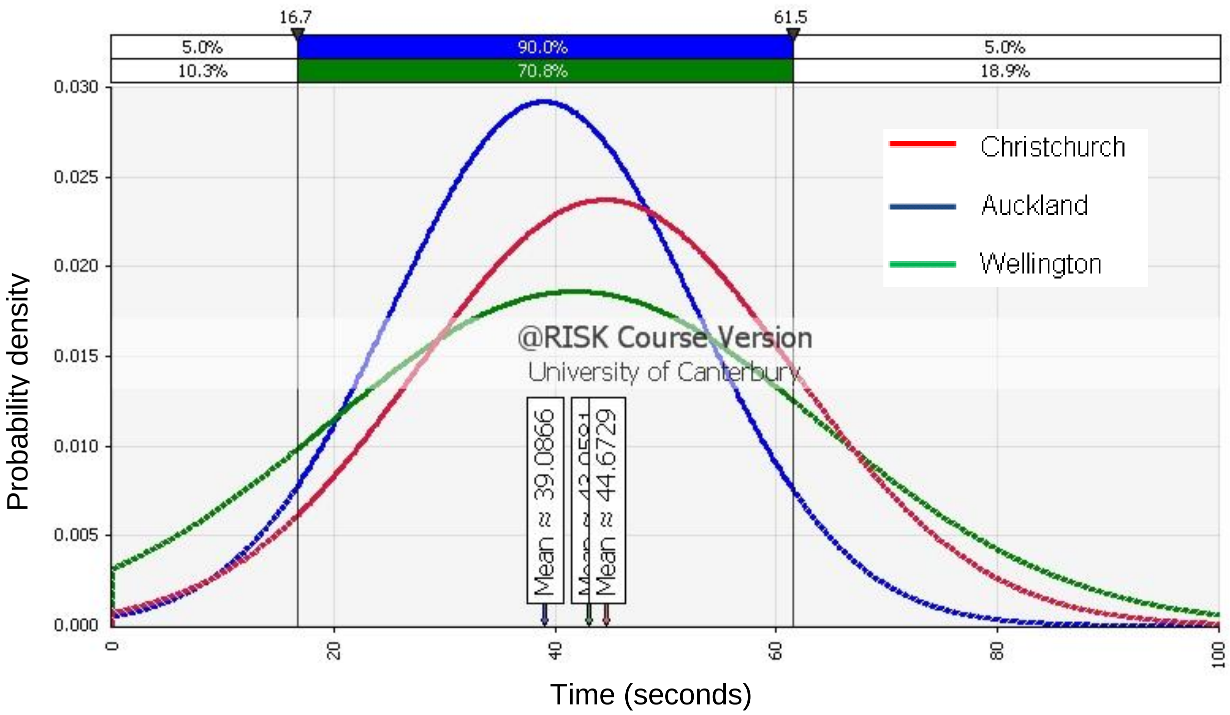


Figure 27 Fitted normal distributions of suburban fire appliance response speeds for Auckland μ=39, σ=22.2, Wellington μ=43, σ=16.9 and Christchurch μ=44.7, σ=14.9 in km/h

Comparison between each of the specific cities and suburban travel speeds are shown in Figure 28 to Figure 30.

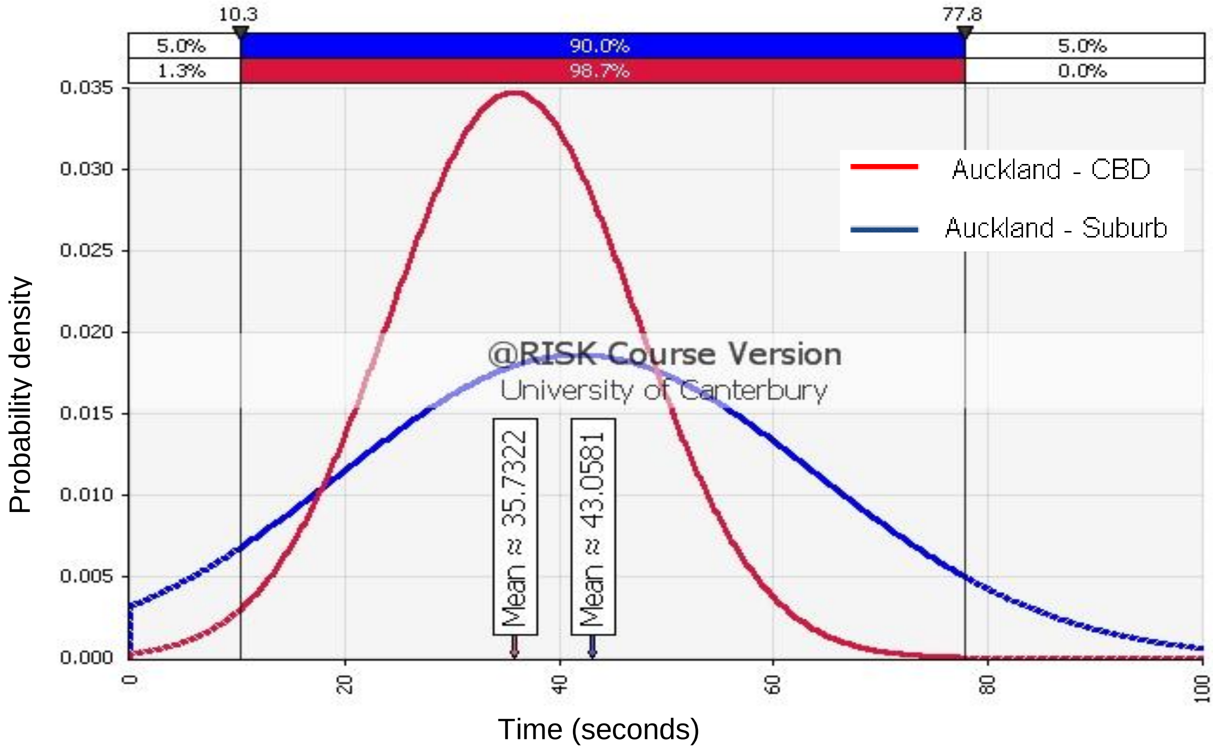


Figure 28 Fitted normal distribution comparisons between Auckland CBD μ=35.7, σ=11.5 and suburban μ=43, σ=22.2 fire appliance response speeds, km/h

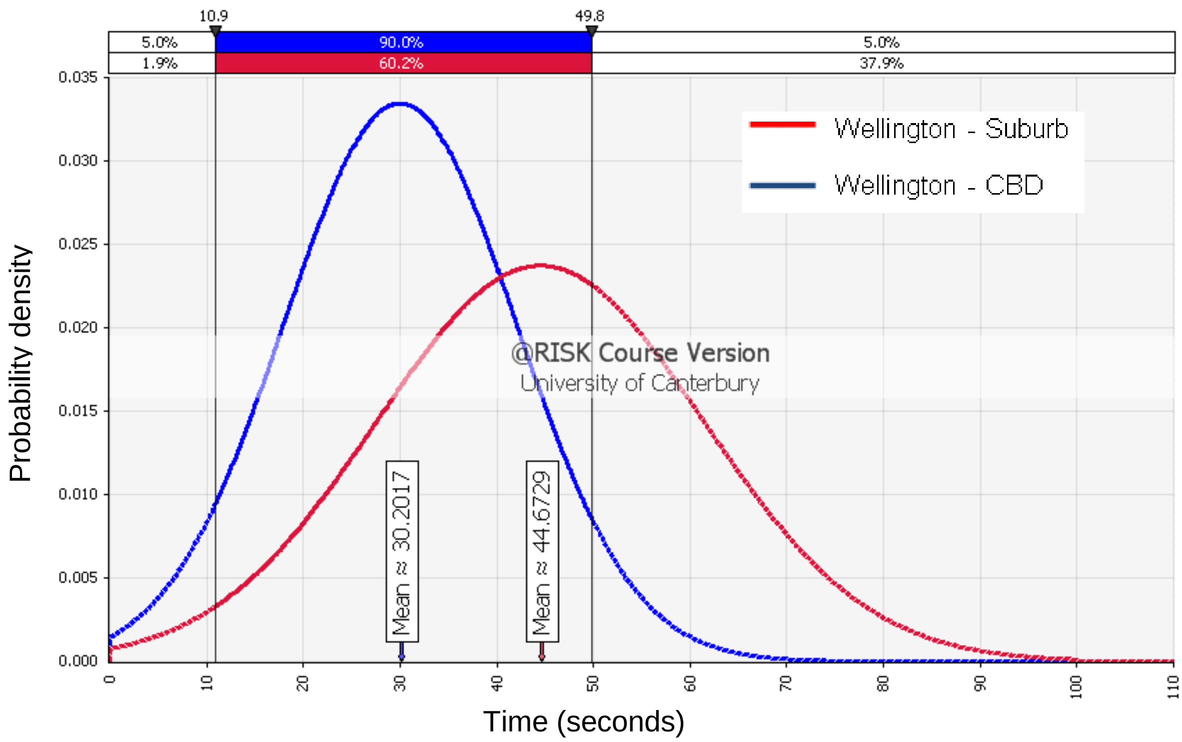


Figure 29 Fitted normal distribution comparisons between Wellington CBD μ=30.2, σ=11.5 and suburban μ=44.7, σ=16.9 fire appliance response speeds (km/h)

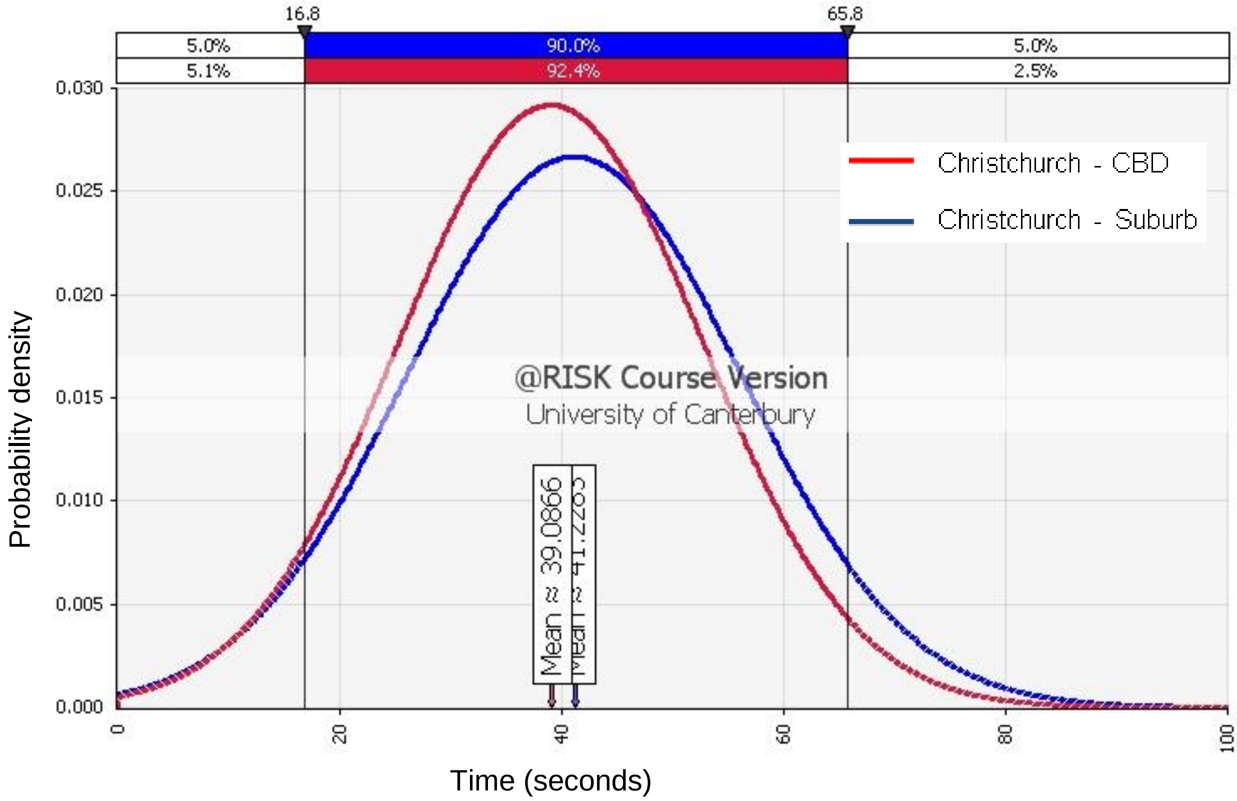


Figure 30 Fitted normal distribution comparisons between Christchurch CBD μ=39, σ=8 and suburban μ=41.2, σ=8 fire appliance response speeds km/h

As can be seen from the distribution comparisons, there are significant differences between the average speeds attained within the suburbs of Auckland (7.3 km/h difference) and Wellington (14.5 km/h difference) compared with the CBD response speeds. However, the Christchurch data indicates little difference in response speeds between the CBD and suburbs (2.2 km/h difference). Given the differences in geographies of the three cities, perceived congestion issues and size of the respective CDBs, it could be expected that there would be a marked difference between the inner CBD speeds and outer suburb speeds for Auckland and Wellington. Also, considering the relatively flat geography of Christchurch city compared with Auckland and Wellington, and the relative size of the CBD and perceived congestion issues faced in the city, it is not unexpected that there would be little difference between the CBD and suburb response times. However, these results are not conclusive in this respect as the results have only been compared for specific stations in specific locations. Further analysis and comparison of all available fire appliance response speeds may prove or disprove this theory.

However, given the results presented it would appear appropriate that different response speed distributions be considered for incidents within the CBDs of Auckland and Wellington compared with their suburbs and that a single distribution only need be considered for incidents in Christchurch. Figure 31 shows the logistic fitted distribution for the combined Christchurch CBD and suburban average response speeds from 165 records. The travel speed distribution for Christchurch should therefore consider all data and include both the CBD and suburb data for this distribution.

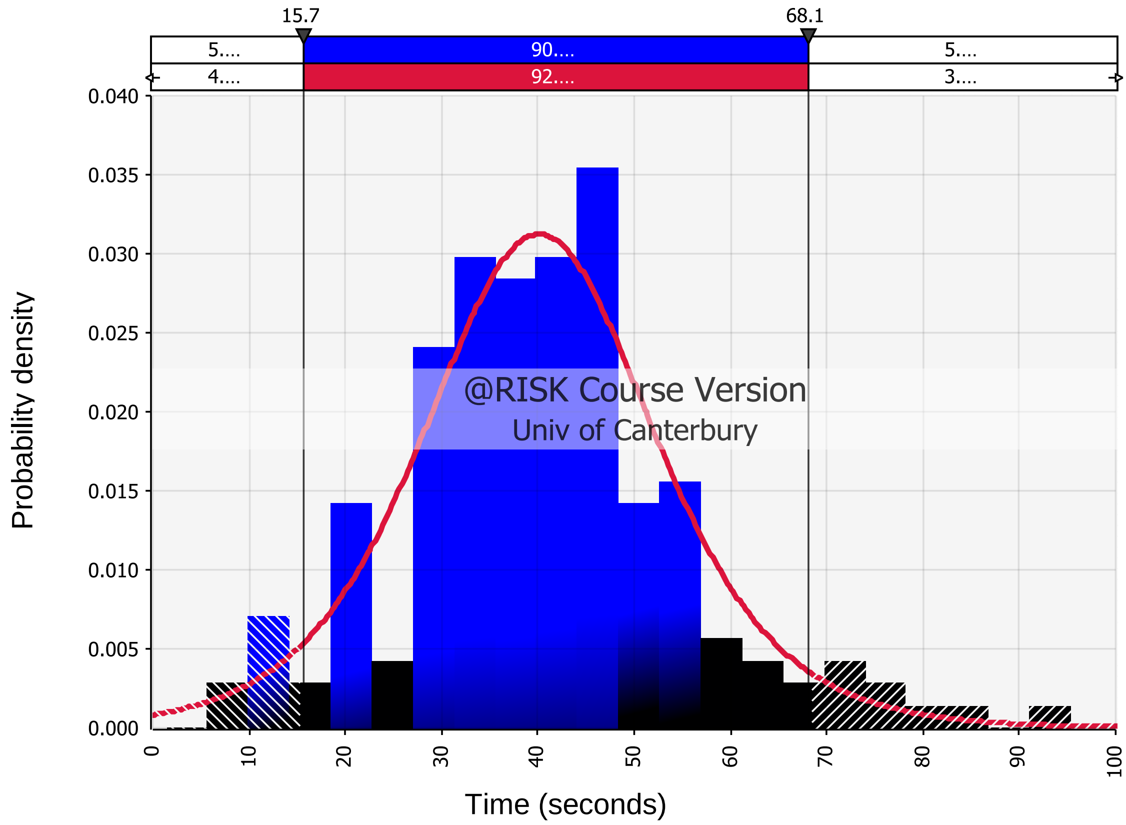


Figure 31 Fitted logistic distribution for all CBD and suburban fire appliance response speeds in Christchurch μ=40, σ=8, km/h

7.5.11. Speed-Distance Relationship

The data was analysed to determine whether any correlation between speed and distance existed as found in previous studies (63). All data sets were analysed including comparing the results found between the UFD and RFD, CBD and suburban data sets. The data was also assessed to find any resulting relationship and to try and define a 'short' distance and a 'long' travel distance appropriate to New Zealand conditions by the method given by Tillander (43). No definitive relationship was found indicating that Tillander's deterministic values are not relevant to New Zealand given the variables that can affect response speeds. On this basis, given the large amount of data analysed, the fitting of distributions to this data is considered to be the most appropriate approach.

Further data analysis for appliance speeds within the larger cities based on larger data sets could identify if any trends similar to those found in these previous studies exist within the larger cities such as Auckland and Wellington or within specific rural areas. Further scrutiny of the data separated into evening and daytime responses could also warrant further analysis to identify any relationships that might exist. However, for the purposes of this research and FBIM model data, such further scrutiny is not considered of substantial benefit.

7.5.12. Minimum Response Speeds

Lower and upper bounding speeds were considered from the data sets used which included removal of data sets returning values below 0 km/h or those with no returned speed, of which there were 25 records. Also, calculated average speeds well in excess of 100 km/h, of which there were 225, were removed as many of these times exceeded the maximum obtainable appliance speed and that set down within NZFS driver policies. For example, 145 values returned indicated average travel speeds in excess of 140 km/h, which is extremely unlikely. For the purposes of using the distributions found within the data sets, the distributions found must be truncated to remove travel speeds of 0 km/h, otherwise the time taken to respond to any incident will for some instances return an infinite response time. Whilst upper bounding response speeds of 100 km/h were used, this speed is possible under certain conditions for responses in all areas, albeit in very few cases and in few circumstances. However, such high average response speeds are reflected in the distributions found and would produce the very shortest response times that would be possible in reality but which should be discounted in any FBIM analysis as these would represent the very shortest possible response times and a ideal response time to any incident. Thus, it was considered to maintain the 100 km/h maximum response speed which corresponds to New Zealand maximum legal speed limit and that typically specified for the majority of NZFS appliances by NZFS policy.

Consideration therefore needs to be given to the use of a minimum value for the response speed used as part of the FBIM distribution. The minimum values for each data set were analysed as well as the fifth percentile minimum speeds considered. It was found that the samples considered for each of the city and suburban data sets were not appropriate for consideration for the minimum speed as this data set was drawn from specific appliances that were the first arriving appliance within their own area, therefore minimum response speeds would be optimised to a certain degree within this data set. As a result, the larger data sets for the UFD and RFD were used. Fifth percentile speeds were chosen as representative of the minimum response speeds, as this removed the data at the end of the tail distribution arising from possible anomalies.

The returned fifth percentile average lower response speeds were found to be 12 km/h for appliances within the UFD and 15 km/h for appliances within the RFD. The lower speeds are considered appropriate given that other appliances should be able to respond to an incident should the closest fire appliance respond at such a slow speed due to traffic congestion or another coincident on that particular route causing such a low average speed.

7.5.13. Discussion

The average fire appliance response speed distributions to actual incidents for the July 2008 to June 2009 period have been shown assuming that appliances have travelled the most direct route from the fire station where the appliance is located to the incident. Travel speeds have been attained for all locations within the NZFS Urban and Rural Fire Districts and for city locations including Auckland, Wellington and Christchurch. As the data is appliance-specific only, single appliances with sufficient data samples to conclude a suitable distribution have been used. As these appliances are located in the CBDs of New Zealand's main cities, they experience the greatest number of fire attendance and thus provide suitable data for analysis. For design purposes, where the building or proposed incident location is known, the distribution speeds presented should be used together with knowledge of the relevant fire station address and shortest travel distance between the two locations to find the travel time. A suitable software tool such as Google™Maps (70) can be used to ascertain the shortest distance and likely route an appliance will take from the fire station to the incident location.

For any analysis requiring consideration of fire appliance response speeds to incidents, the following normal distributions are proposed in Table 13.

Table 13 Proposed New Zealand data additions to FBIM Table F (km/h)

Location of incident	μ	σ	Minimum value	Maximum value	Sample size
Inside UFD	37.8	15.6	12	100	5308
Inside RFD	54	20.4	15	100	817
Auckland – CBD	35.7	11.5	12	100	79
Auckland – Suburb	41.8	22.2	12	100	42
Wellington – CBD	30	12	12	100	85
Wellington – Suburb	44.5	16.9	12	100	46
Christchurch	40.5	14.9	12	100	163

The FBIM provides for response times to be estimated based on a radial distance option and also suggests that the distances used from the responding stations should be calculated using the station location if assuming a volunteer appliance response, or to base the calculated response distance from the furthest location from the building of interest within the appliance's designated turnout area if assuming a career fire-fighter response. At the time the FBIM was produced, software was not easily available to calculate the directions and distance between specific locations. To provide a reliable and relatively straightforward means of calculating the distance and response time using the given appliance travel speeds, a 1.5 multiplier was recommended where the straight line between locations was known or could be easily measured from a street directory or map. As software is now available via the internet to calculate the quickest route and distance between address points, this calculation method is no longer required. Also, given that the derived speeds have assumed that the appliance is located at its specific station and have taken into account response times that have occurred when the appliance was not at its station, assuming a response from a location other than the appliances' designated station is not necessary for a New Zealand FBIM calculation using this proposed data. This specific issue is addressed further in section 8.2.

7.6. Fire-Fighting Activity Data

This section presents data and fitted distributions, where relevant, to the times associated with individual tasks undertaken by fire fighters at fire incidents. The data presented in this section follows that presented within Tables G to Z from section 7 of the FBIM manual required for population of charts 5 onwards. The data presented in this section has primarily been taken from data collected using specific exercise drills formulated to collect the individual times associated with each activity. Eight standard proforma FBIM exercises were originally developed to collect the data that is currently presented within the FBIM manual. These exercise sheets have been significantly modified and extensively trialled to reflect current NZFS equipment and operational procedures. The latest version of these exercise sets are provided in Appendix F.

The drills have been made available throughout the NZFS to allow for data collection from as many individual brigades as possible. Whilst data collection is ongoing, this section presents the data collected to date and provides an analysis of the following type of operational data:

- fire-fighter horizontal travel speeds including
    - travel in personal protection equipment (PPE)
    - travel in PPE with equipment
    - travel in PPE including BA with or without equipment
    - travel in BA with hazardous incident suit;
- fire-fighter vertical travel speeds including
    - ascending stairs in BA with equipment
    - ascending stairs in BA with hose including high pressure hose reel and low pressure deliveries
    - descending stairs in BA
    - rest breaks required;
- hose operations
    - removal, connection and charging of feeder hose between hydrant and appliance
    - removal and connection of supply hose from appliance-branch
    - removal and connection of hose from appliance to hydrant inlets
    - charging of delivery hose from appliance
    - connection and charging of hose from hydrant outlets

    - travel with high pressure delivery;
- specific equipment times
    - removal of equipment for establishing hydrant supply
    - preparing and flushing in ground hydrant
    - removal of high rise pack including associated tools;
- breathing apparatus and equipment
    - donning BA and preparing for entry
    - donning BA and hazardous suit
    - decontamination unit and setup
    - assembling safety equipment
    - obtaining hazardous materials information from communications centre;
- search and rescue operations
    - building perimeter search times
    - rescuing missing persons;
- aerial appliance times
    - positioning of aerial appliances after initial arrival
    - appliance setup for each available aerial appliance
    - preparation and safety checks associated with aerial appliances
    - times taken to train and elevate aerial appliance 180^{o}
    - times taken to charge monitor;
- obtaining water from static water sources
    - positioning of appliance
    - removal of suction hose and connection to tank and appliance
    - time taken to prime suction hose from tank
    - time taken to secure hard suction
    - time taken to lower and charge suction hose from open water.

So direct comparison with the data currently presented within the FBIM manual can be made, the following data is presented in the same format and headings as that given in section 7 of the FBIM manual (5).

7.6.1. Set-Up Times

Data regarding setup times has been historically lacking, although it has been recognised that the time it takes to set up at a fire scene may be two to three times longer than the time taken to respond to the incident (61). FBIM analysis prepared for various building consent applications have also identified that the response times for fire appliances to travel to the incident locations may account for only 20% of the time taken between the incident commencing and water application. Where incidents are located on the upper levels of high-rise buildings it could be expected that the response times for fire appliances to travel to the incident locations may be insignificant when the overall fire service response times including travelling up stairs (if required) and set up times were to be assessed. The following section presents the data associated with FBIM charts 5–12.

7.6.2. Time Delay for Building Entry and Warden Communications

Table G of the FBIM considers the time delays associated with any security procedures that may delay entry of fire service personnel into the building. The FBIM requires that the designer consider and supply information relating to any delays associated with making entry to a secure building. Depending on the level and nature of security systems or features in place, this can potentially add a substantial delay in providing access to a building for arriving fire fighters. However, where secure facilities include permanently manned facilities and fire wardens, such as prisons, there can be advantages and increased efficiencies provided to fire brigades by advanced notification of the situation as it develops and reduced time delays in identifying the specific location of the incident. Such time delays can be difficult to establish; however, for specific security features such as gaining access through doors, designers should be able to provide specific time delays for each individual secure component restricting access to specific areas of a building. Where wardens or security guards are present, information relating to their availability and the times taken for them to establish communications and confirm the nature of any incident can normally be provided in New Zealand by evacuation consultants and those familiar with similar existing facilities using established procedures and protocols.

The NZFS is legislated under the Fire Service Act to make entry to any land and buildings under emergency conditions, which includes breaking into any building or structures. However, if on arrival at a secure building a fire is not visibly identified, fire fighters will not typically force entry or damage property unnecessarily. In these situations where a fire or other emergency cannot be readily established, contact with a designated key holder such as a security company will try and be established. This could cause significant delays in making entry if wardens or staff are not permanently located on site and available at the building’s main entrance on arrival. The NZFS can also be provided with keys and access codes to specific buildings which can reduce the time taken to make access. However, any keys held will typically be located at the fire station which is within the first response area of the building, identified by a 'key box number'. Due to the number of keys held, they are not carried on fire appliances and need to be specifically identified on the turn out and notification procedure when called to a specific building. Once the key box number has been identified, they need to be located and picked up by fire fighters responding from that specific station. These issues affect the reliance on the use of keys given to the NZFS and having to ensure that they remain current makes it difficult to establish confidence in relying on this as a method for reducing any delays that can be associated with accessing land and buildings. Keys are recommended to be supplied to the NZFS as they should minimise damage that could be caused when responding to unwanted alarms at buildings. However, they should be ignored for the purposes of any FBIM calculation and not factored in to any times provided by designers and agreed as appropriate by the relevant fire brigade who may also have working knowledge of similar facilities.

7.6.3. Time to Force and Make Entry

Table I within the FBIM manual provides eight different time values associated with common types of doors and gates that fire fighters need to open to make entry into buildings. It is understood that the times provided within the FBIM were provided by experienced fire fighters using the Delphi method. The time taken to force entry through a door or other feature designed to prevent entry can vary significantly depending on the level of security, type of feature and many other factors including the level of urgency which may dictate the methods used to gain entry. Forcible entry tools are generally standard across the NZFS fleet, of which a typical selection of 'striking and prying tools' as carried on a typical NZFS appliance is shown below in Figure 32.

Figure 32 Typical NZFS rescue tools

During the course of this research, using available video footage and witnessing emergency incidents, two values have been validated including that associated with opening an 'outward opening, side-hung fire door' and a 'chained gate' using forcible entry tools from an appliance. For both of these features, the times witnessed were within five seconds of the reported values of 180 and 45 seconds, respectively, given in the FBIM. This indicates that the times are appropriate for use in New Zealand. Given the difficulties associated with determining such times due to the damage associated with forced entry techniques employed by emergency services, it is difficult to establish specific times for the individual characteristics associated with specific features. For the purposes of an FBIM analysis however, and until other research can be undertaken and shown as appropriate, the times given within table I of the FBIM as reproduced below are still considered reasonable values for this specific time component.

Table 14 Times to force entry FBIM Table I

Door type	**Time (s)**
Inward opening, side-hung door	30
Outward opening, side-hung fire door	180
Outward opening, side-hung, solid-core door	90
Inward opening, hollow-core door	15
Outward opening, hollow-core door	45
Glass door	15
Roller security/steel door	220
Chained gate	45

Access through doors and gates where keys are present will be determined on the specific nature of the door or gate and its locking mechanism and ease of use, etc. The level of variance associated with each individual door would, however, not be expected to vary so considerably that it would have a bearing on the FBIM predictions. However, a time component does need to be incorporated for any known locked doors or gates that will need to be negotiated to make access to the location of any incident. The three values provided within the FBIM Table J have not been verified specifically except for the common, everyday experience of opening locked doors. Given the relatively insignificant times provided by the FBIM, there is no indication that they are not still appropriate for continued use and are appropriate for acknowledgement of an associated minimal delay that is likely to occur when accessing a locked door or gate should a key be available.

Table 15 Time to gain entry (with keys) FBIM Table J

Door type	**Time (s)**
Side-hung door	10
Roller security door	30
Gate	30

7.6.4. Time to Resolve Way Finding

The FBIM table K provides five different time components to take into account the difficulties that can be found with having to locate specific areas of complex buildings. The addition of this time component is dependent on whether pre-operational planning has been undertaken by the relevant fire brigades and therefore whether specific knowledge of the building and its layout could be known by responding fire fighters. The NZFS undertakes pre-operational planning to familiarise local fire crews with specific risks and buildings of interest within their relevant fire response area. While all NZFS personnel undertake pre-operational planning, it is difficult to establish what level of benefit will be achieved if such operational planning has taken place prior to any incident. Any perceived benefit is also reliant on the specific knowledge of the first responding fire fighters. The FBIM discusses a number of issues associated with way finding and states that research has suggested the benefits of undertaking pre-operational planning and the expected benefits that this may bring to an FBIM calculation, such as increased travel speeds. No reference is provided within the FBIM to enable scrutiny and validation of these specific references against New Zealand conditions. However, experience to date would suggest that the benefits of pre-operational planning and the identification of higher hazard risks, such as hazardous substances and the like, whilst essential for emergency incident planning, hazard avoidance and incident control, would have little relevance to an FBIM analysis in way finding within a particularly complex building. This can be partly explained given that there are four shifts worked at a career station and that not all fire fighters could be expected to be specifically familiar with buildings in their first response areas. Also, considering other factors such as staff rotations and regular replacements by unfamiliar fire fighters, even when an appliance staffed by those that had undertaken pre-operational planning is first to arrive at an incident, it is likely that the fire fighters could still face some time delays when way finding in large and complex buildings. It would therefore be considered appropriate and conservative to always consider an additional time component associated with way finding in complex buildings.

The FBIM recognises that this can be a subjective issue depending on the specific nature of the building and its complexity for fire-fighting purposes. The consideration of appropriate signage and facilities to access specific parts of the building including secure access will also provide additional problems depending on the specifics of each building. Therefore, the FBIM recommendation to discuss these issues with the relevant local fire service is also considered appropriate; otherwise the times provided within the FBIM as repeated below should be incorporated.

Table 16 Time to resolve way finding FBIM Table K

Complexity/building size	**Time (s)**
Multi-level, numerous enclosures & passages	30
Multi-level, open plan	10
Single storey, numerous enclosures & passages, floor area > 5000 m^2	45
Single storey, open plan	10
Single storey, numerous enclosures & passages, floor area < 5000 m^2	30

7.6.5. Time for Information Gathering

The times associated with information gathering are based on the information that first confronts responding fire fighters at the building's main attendance or arrival point. Typically buildings of any significance will be provided with some level of detection system requiring an FAP to be provided at the fire service's main or designated attendance point. Some complex and tall buildings will also be provided with additional facilities such as sector location panels for sites containing multiple buildings, which provide information as to which specific building needs to be accessed. Other buildings such as high-rise buildings will contain fire systems centres which are dedicated rooms containing any critical fire safety equipment or systems that could be expected to be operated by fire fighters during an incident and also detailed building information on plans and information to other specific building features that could be of relevance during a fire or other emergency. There is much research available discussing and addressing what information is currently available to fire fighters on modern alarm panels and what is likely to be available in the future in new buildings, including the advantages that can be gained to improve the tactical decisions made by responding fire brigades as well as improving their effectiveness and the safety of the fire fighting (71)(72). However, for the purposes of initial fire-fighter response to a building and initial determination of the location of a fire, of specific interest to an FBIM analysis is the information readily available on the FAP index which immediately identifies the type of system that has activated, i.e. sprinkler, heat or smoke detector activation and the specific location of the fire. The FBIM provides for three time values that are dependent on the size of the floor area and references compliance with the Australian Standard AS 1603.4 Automatic Fire Detection and Alarm Systems – Control and Indicating Equipment. Since the original publication of the FBIM, there have been significant advances in fire alarm-indicating equipment and the requirements for FAP indexes. Given the relatively basic and straightforward nature of modern FAP indexes irrespective of the complexity of the specific building, it is unlikely that there will be significant differences in the times taken to establish the location of the first detector activated. Providing access to the FAP index is relatively straight forward and further interrogation and information gathering from more complex systems and from fire systems centres is likely to be undertaken by crews arriving after initial entry has been made. Therefore, it is considered that only the time taken to establish the initial location of the incident is required for this specific component of the FBIM analysis. For modern fire alarm panels complying with the relevant New Zealand standard which meets the approval of the NZFS, is likely to be accessible and information understood within 30 seconds, irrespective of the floor area of the building. Therefore, a time of 30 seconds is considered appropriate and recommended without further research or information.

Table 17 Proposed New Zealand data additions to FBIM Table L

Activity	**Time (s)**
Time for information gathering from a fire alarm panel complying with NZS 4512	30

Chart 5 of the FBIM which shows the 'time taken for initial determination of fire location' does, however, suggest that the times taken to communicate with a fire warden and those taken to gather information from an FAP be considered in isolation from each other. Experience at incidents would indicate, however, that fire fighters would typically interrogate the FAP as a matter of course and best practice as well as seeking any information from available wardens. Therefore, it is recommended to include both the times taken to communicate with any wardens and to interrogate the FAP in FBIM Tables H and L within any FBIM analysis.

7.6.6. Time to Dismount Appliance and Don BA

Table M within the FBIM provides a single statistical data set to represent the times taken for fire fighters to dismount from an appliance and don BA sets. For any structural fire, fire fighters operating within or around any fire will be required to wear BA. When arriving at an incident the donning of BA will be the first task completed. In the NZFS, BA is either mounted within the seats of fire appliances allowing for BA to be donned before dismounting the appliance or will be located within a locker on the appliance, which requires donning after dismounting the appliance. Typically, appliances for full-time fire fighters will contain seat mounted BA while BA in lockers are common for volunteer fire fighters. Through observation and experiment this research has identified differences in the times associated with these two scenarios. The distributions found within the data collected to date are shown in Figure 33 below, overlaid with the Australian data. A normal distribution was found to fit all of the data sets well. Although limited data has been collected, with fewer data sets for the seat-mounted BA times than for locker-mounted BA times, the differences reported here appear to be consistent with the times witnessed from actual incident experience.

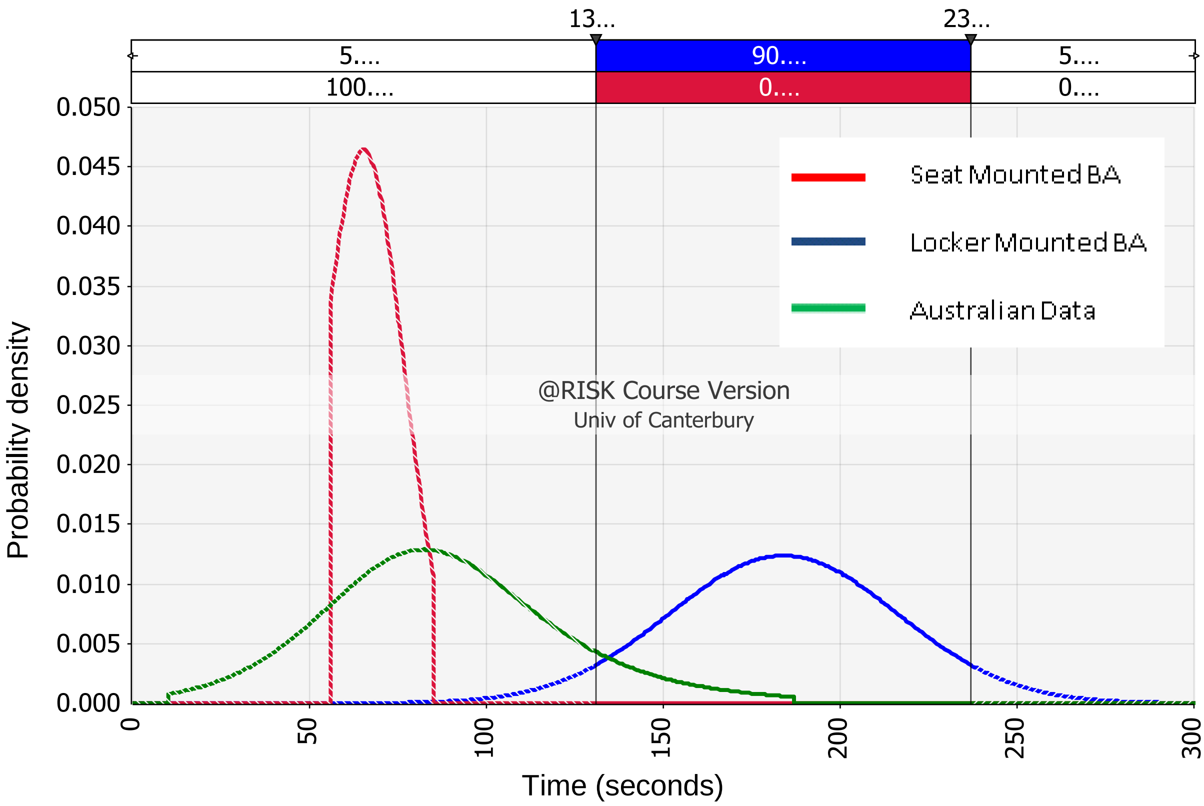


Figure 33 Distributions found for the times to dismount an appliance and don BA (seconds)

Two separate times are therefore presented for the different types of appliances that may respond and require different methods of donning BA. Once BA has been donned, safety procedures need to be undertaken before fire fighters will enter buildings, including the donning of BA masks and cylinder pressure tests as well as entry control procedures. These safety procedures can be either undertaken immediately after donning BA or once other tasks have been completed such as the laying of hose up to the entry point of a building. The data collected as part of the project has allowed for the variability that occurs with the safety procedures dependent on the specific tasks undertaken before entry to a structure or before fire-fighting operations commence. The times associated with the safety procedures have been added together and included in a single time for inclusion within an FBIM analysis.

Table 18 presents the times taken to dismount an appliance and don BA for both seat and locker mounted BA with the FBIM data for comparison. As can be seen, there are substantial differences and time savings associated with the use of seat mounted BA. Unless specific information is known or available about the appliances that would likely arrive at the building, when undergoing an FBIM analysis it can be assumed that an appliance manned by career fire fighters will have seat-mounted BA and one manned by volunteers will contain locker-mounted BA. Given that the NZFS current and modern vehicle purchases are being based on this assumption, this should be appropriate for both current and future FBIM analysis.

Table 18 New Zealand and FBIM Table M data represented using normal distributions for times associated with breathing apparatus

Time for different BA configurations (seconds)	μ	σ	Minimum value	Maximum value	Sample size
NZ data – locker-mounted BA	184	32	134	236	8
NZ data – seat-mounted BA	65	12	56	85	4
Australian FBIM data	88.1	34.9	10	187	259

Based on the minimal number of data sets collected so far, the Australian data compares relatively well with the NZFS seat-mounted BA times. As would be expected with a larger data set however, the standard distributions found are larger with the larger number of Australian data sets. The shape of the distributions for the locker-mounted BA times are similar to the Australian data, which is a function of both the larger number of records and the variation that could be expected with such a task. It is unknown how the BA sets were mounted within the Australian distributions although given the comparison with the NZFS seat-mounted BA times, it would appear that they included seat-mounted BA arrangements or that there is another factor that allows Australian fire fighters to don BA faster than the NZFS equipment allows.

The following distributions are recommended for these tasks until further research and more data sets are available to increase the confidence in these results:

locker-mounted BA – normal μ=184, σ =32, min=134, max=236;

seat-mounted BA – normal μ=65, σ =12, min=56, max=85.

7.6.7. Time to Don Safety Equipment

This specific task relates to the time component associated with donning BA worn either on the inside or outside of hazardous incident suits. Depending on the nature of the incident, a chemical splash suit and BA will be worn in all situations where fire fighters are likely to come into direct contact with chemicals or other hazardous substances that are in a solid or non-vaporising liquid state. Gas suits and BA are worn by fire fighters when they are likely to be exposed to chemicals or other hazardous substances that are either vaporising liquids or gases. There are major differences between the two general types of suits required to be worn and individual makes of each type of suit. These are all likely to have different donning times associated with each suit.

At the time of completing this research, the NZFS was in the process of updating all of its hazardous incident suits and hazardous materials support vehicles. Due to the currently employed 'long-life' gas suits nearing the end of their useable life span, the NZFS are changing to 'limited-life' suits which have significant characteristic differences that could affect fire-fighters' response times compared with the suits currently used. Because of the ongoing trials of these new suits and related equipment, no data has been established for fire-fighter activities associated with hazardous substance suits or equipment at this time. It is expected that during these trials specific data relating to each individual type of suit and the generic equipment used can be collected for future presentation within the FBIM manual.

Given the expected variation of experience and issues associated with wearing hazardous incidents suits, there is no reason to dismiss the reasonably long times predicted by the current FBIM data. Therefore, if an analysis considering hazardous materials is required to be undertaken and a value associated with the time to don BA and a hazardous incident suit, until further data can be established the following FBIM distribution is recommended to be used:

N – lognormal $\mu = 584.4$, $\sigma = 298$, min = 200, max = 1155.

7.6.8. Time to Conduct Safety Procedures or Assemble Safety Equipment

FBIM table O considers the 'time to conduct safety procedures or assemble safety equipment'. These times are mainly associated with hazardous incidents and, as such, only data associated with the flushing of hydrants (a mandatory task required to be completed before supply water to a fire appliance from a street hydrant) has been collected. Figure 34 shows the normal and lognormal distributions fitted to the NZFS and Australian data respectively. Only five samples of hydrant flushing have been collected to date and so cannot be considered statistically significant. However, the distributions found show similarities with the Australian data having a larger standard deviation as would be expected with a larger data set for a very similar task.

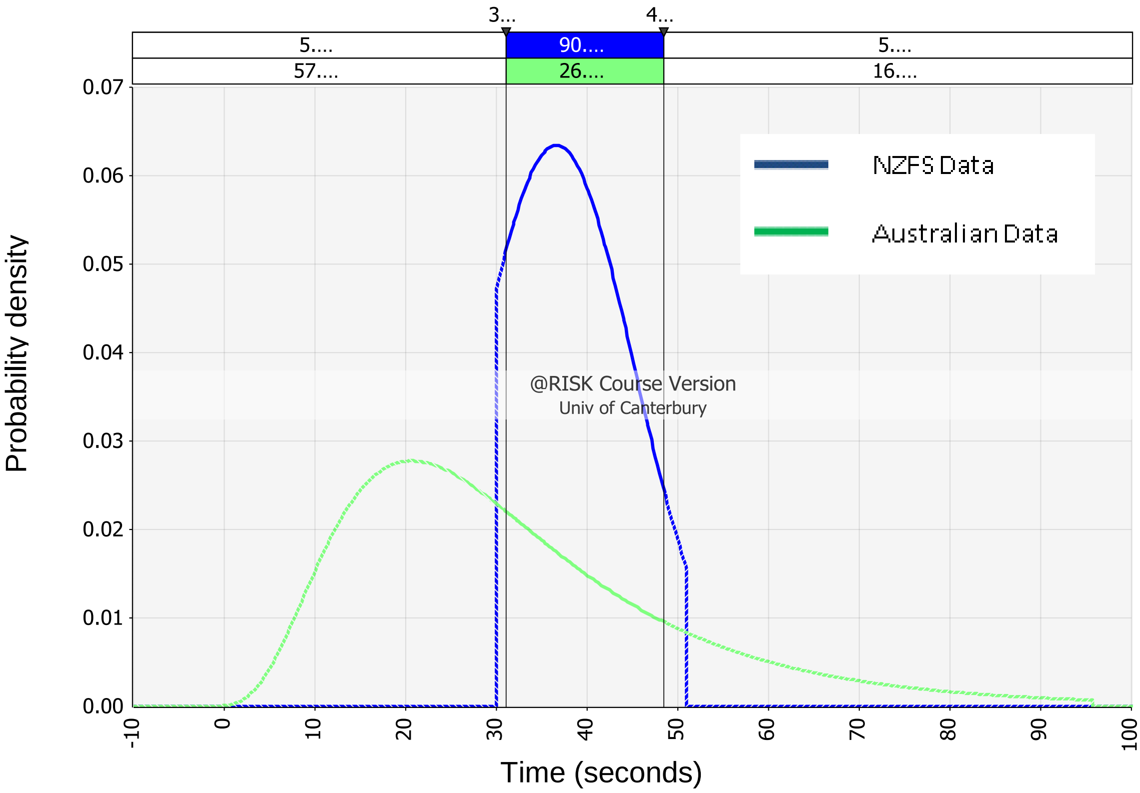


Figure 34 Australian and NZFS distributions found for the times taken to flush a street hydrant (seconds)

Table 19 provides the times taken from the FBIM manual table O with the data collected to date for the hydrant flushing task. As the number of data points collected is so small but presently shows a close comparison to the Australian data, it is recommended to use the Australian data sets until further NZFS data is collected. There is no information to suggest that there would be any reason for these times to be significantly different considering the tasks and similarities between NZFS and Australian equipment.

Table 19 FBIM Table O Time to conduct safety procedures or assemble safety equipment

Safety procedure	Time (s)				Sample size
	μ	σ	Minimum value	Maximum value	
NZ data					
O1 – Flush hydrant	36.6	7.7	30	51	5
Australian FBIM data					
O1 – Flush hydrant	32.8	20.6	4	100	124
O2 – Obtain hazardous material information from communication centre	701.0	409.5	153	1400	49
O3 – Decontamination unit set up	764.9	186.1	624	1170	7
O4 – Assemble miscellaneous safety equipment	290.6	132.1	97	465	7

The following distributions based on a re-examination of the existing Australian data are suggested for these tasks:

O1 – lognormal $\mu = 37$, $\sigma = 20.3$, shift −4.24, min = 4, max = 100;

O2 – Weibull $\alpha = 1.2$, $\beta = 591$, shift 145.36, min = 153, max = 1400;

O3 – lognormal $\mu = 245$, $\sigma = 1253$, shift 623, min = 624, max = 1170;

O4 – logistic $\alpha = 301$, $\beta = 79$, min = 97, max = 465.

7.6.9. Time to Remove Necessary Tools from Appliance

FBIM Table P provides three times associated with removing forced entry tools, hydrant equipment and high-rise packs from an appliance. A single time to collect forced entry tools from an appliance is given in the FBIM as 25 seconds. No NZFS data has been collected representing this task; however, considering stowage of tools upon fire appliances do vary between different types of appliances, and between different tools and equipment, 25 seconds would appear to be a representative time appropriate for NZFS conditions in lieu of appropriate data. This is also true for the removal of high-rise packs from appliances. High-rise packs are generally stored within lockers to enable quick and convenient access. Again, considering similar stowage arrangement to that in Australia, there is likely to be little difference in practice between countries and the same data is recommend until sufficient NZFS data can be collected.

Five data sets have been collected so far for the times taken to remove hydrant equipment, the hydrant standpipe, bar and key. Figure 35 shows the distributions found using the Australian FBIM and NZFS data collected to date. Considering the number of records collected so far, the distributions compare relatively well with the NZFS data represented by 60% of current FBIM data for 125 records. This data is provided within Table 20 with the recommended distributions using the existing FBIM data following.

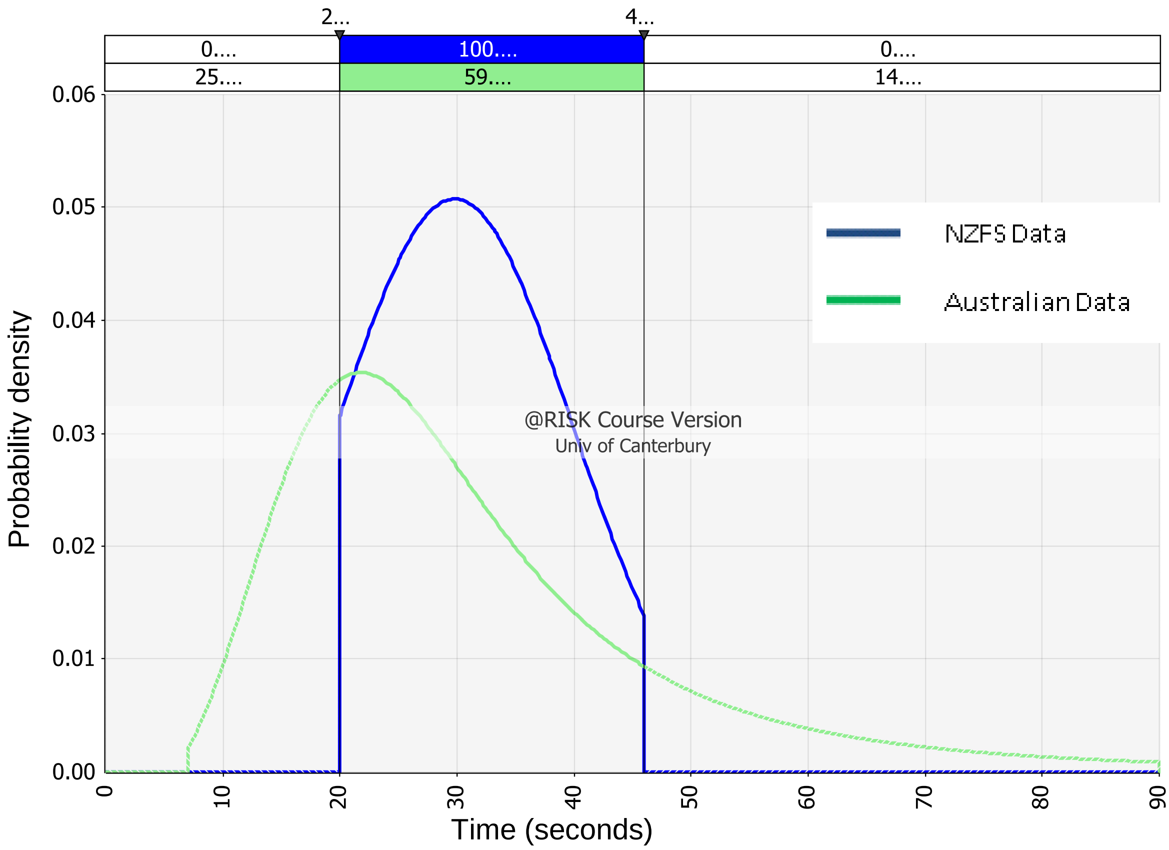


Figure 35 Australian and NZFS distributions found for the times taken to remove hydrant equipment (seconds)

Table 20 FBIM Table P including NZFS data for the collection of hydrant equipment and high-rise packs

Tools/equipment	Time (s)				Sample size
	μ	σ	Minimum value	Maximum value	
NZ data					
P1 – hydrant equipment	29.8	9	20	46	5
P2 – high-rise pack or similar	33	N/A	N/A	N/A	1
Australian FBIM data					
P1 – hydrant equipment	32.5	18.1	7	90	125
P2 – high-rise pack or similar	13.5	6.0	5	30	39

The following distributions using @Risk to re-evaluate the Australian data suggests the following distributions for these tasks:

P1 – loglogistic $\Gamma = 5$, $\beta = 22.5$, $\alpha = 2.7$, min = 20, max = 46;

P2 – lognormal $\mu = 13.3$, $\sigma = 6.3$, shift 0.18, min = 5, max = 30.

7.6.10. Fire-Fighter Horizontal Travel Speed

FBIM Table Q provides the times associated with fire-fighters' horizontal travel speeds considering different levels of PPE and equipment. As would be expected, the greater the level of equipment and PPE worn is reflected by decreasing travel speeds due to the increasing weight and encumbrance. No NZFS data has been collected for fire fighters dressed in full hazardous incident suit with BA, so the FBIM data would need to be used until further data can be collected and assessed. A total of 23 data samples have been collected so far for fire-fighter travel speeds with the various levels of PPE and BA. As with the FBIM data, this has been collected without any smoke obscuration hindering movement or the fire fighters' way finding. An appropriate safety factor would need to be considered if considering smoke-obscured conditions.

For fire fighters dressed in PPE (turnout uniform), the data collected so far suggests a slightly faster rate of travel than that given within the FBIM. This is possibly a function of the relatively small data set and limited range of conditions fire fighters have been subjected to. It would be expected that given a larger and more varied range of conditions such as different weather and lighting conditions and other factors, the standard deviation would increase with more data sets collected. The same is true for fire fighters carrying equipment and for those wearing BA. However, it is not possible to determine this given the relatively small data set collected to date. Therefore, until further data is collected and given that all of the NZFS data falls within the FBIM data ranges, it is considered appropriate to continue to use the existing FBIM data for these travel speeds.

Table 21 FBIM Table Q including NZFS data for fire-fighter travel speeds

Travel conditions	**Speed (m/s)**				**Sample size**
	μ	**σ**	**Minimum value**	**Maximum value**	
NZ data					
Q1 – dressed in turnout uniform	2.7	0.61	1.84	3.68	9
Q2 – dressed in turnout uniform with equipment	1.5	0.41	1.00	2.27	10
Q3 – dressed in turnout uniform in BA with or without equipment	0.54	0.22	0.18	0.75	4
Australian FBIM data					
Q1 – dressed in turnout uniform	2.3	1.4	0.32	6.25	246
Q2 – dressed in turnout uniform with equipment	1.9	1.3	0.13	6.00	159
Q3 – dressed in turnout uniform in BA with or without equipment	1.4	0.6	0.28	3.33	111
Q4 – dressed in full hazardous incident suit in BA	0.8	0.5	0.13	2.5	48

The following distributions using @Risk to re-evaluate the existing Australian FBIM data are suggested for these tasks:

Q1 – loglogistic $\Gamma = 0.12$, $\beta = 1.8$, $\alpha = 2.7$, min = 0.32, max = 6.25;

Q2 – Weibull $\alpha = 1.4467$, $\beta = 2.0271$, shift 0.10346, min = 0.13, max = 6;

Q3 – logistic $\alpha = 1.3$, $\beta = 0.3$, min = 0.28, max = 3.3;

Q4 – Weibull $\alpha = 1.3$, $\beta = 0.76$, shift 0.13, min = 0.13, max = 2.5.

7.6.11. Fire-Fighter Vertical Travel Speeds

As the travel speed inside a lift will be dependent upon the specific design of the lift proposed or present within the building, the ascent speed of the lift should be provided by the designer. Strakosch (73) provides a number of lift ascent speeds within table 10.7 of the Vertical Transportation Handbook dependent on the class of building and the number of floors present. To assist designers determining lift speeds where they are not known at the time of an analysis, this table has been reproduced in full with speeds converted into metric, which can be used if the actual lift ascent speeds cannot be determined.

Table 22 Recommended lift ascent speeds (m/s)

Number of floors	Class of building			
	Small	Average	Large or prestige	Service
Office buildings (including professional offices)				
Up to 5 floors	1.01 [a]	1.52-2	2.03	1.01 [a]
5 to 15 floors	2.03	2.03	2.54	1.52
15 to 20 floors	2.03	2.54	2.54	2.03
20 to 55 floors	2.54	3.56	3.56	2.54
25 to 35 floors	-	5.08	5.08	2.54
35 to 45 floors [b]	-	5.08 to 6.10	6.10	3.56
45 to 60 floors [b]	-	6.10 to 7.11	7.11 to 8.13	4.06
Over 60 floors [b]	-	-	9.14	4.06
Stores				
Up to 5 floors	150 [a]	1.01	1.52	1.01 [a]
5 to 10 floors	2.03	2.03	2.54	2.03
10 to 15 floors	2.54	2.54	2.54 to 3.56	2.03
Garages				
2 to 5 floors	1.01 [a]	1.01 [a]	1.01 [a]	
5 to 10 floors	1.01	1.52	2.03	
10 to 15 floors	1.52	2.03	2.54	

[a] 0.76 ms^{-1} hydraulic acceptable.
[b] Sky lobby design should be considered for this height.

The FBIM table R suggests a lift loading time of 30 seconds. As well as fire fighters entering the lift this time needs to factor in the additional equipment required to support fire-fighting operations in high rise buildings including additional breathing apparatus sets and forcible entry tools, and also needs to include a time component for the fire fighters to familiarise themselves with the make and style of lift and to operate the lift using the appropriate keys. No specific data has been collected to establish a different time component or suggest a suitable distribution for this task. However, given the variables discussed above, 30 seconds would appear to be a reasonable time to allow for the lift loading component to occur.

7.6.12. Time for Hindrance Factor Caused By Occupants Evacuating

The FBIM provides no recommendations for any hindrance factor that can be caused by occupants evacuating a building coincident with fire fighters trying to make access. FBIM Table S refers designers to the evacuation model being used for the egress analysis and suggests that they determine an appropriate factor.

Section 0 presents specific research conducted to determine fire-fighter vertical travel speeds within high-rise buildings and discusses information of importance when considering times associated with ascending stairs. A brief discussion follows considering some of the issues associated with fire fighters trying to make entry to a building at the same time as occupants making egress.

Past incidents have shown the difficulties associated with fire fighters undertaking their duties at the same time as occupants trying to escape from buildings (74)(75). Typically, where insufficient protection is afforded to access stairs, fire fighters will need to set up their equipment and make access into the fire floor from the floor level below the location of the fire. This will mean that once equipment including charged hoses has been laid within a stair it will not be passable safely by evacuating occupants. Also, once entry to any fire compartment has been made it is likely that smoke leakage into the stair will make this untenable to occupants. During many fires, the effects of occupants evacuating have caused significant delays to the commencement of fire fighting and, specifically, suppression operations as fire fighters have not been able to make entry and access to the affected floors until the occupants have completed evacuation of the building and stairs completed emptied (74). In recognition of this particular issue, especially with fire fighting in high-rise buildings, some prescriptive building guidance such as that within the UK (36) and research by NIST

(75) have included and recommended additional requirements for dedicated fire-fighting access stairs to be provided within buildings over certain heights.

Apart from the issues identified above, relevant specifically to high-rise buildings, other buildings such as stadia and the like that contain large exits for mass evacuation should also take into account the effect of fire fighters making entry into the buildings concurrently to occupants evacuating. In these situations, evacuation modelling is normally undertaken which should take into account reduced exit capacity that will result should dedicated access routes into the building for fire fighters not be provided. In such circumstances, the FBIM can be used to quantify likely arrival and access times of responding fire fighters so that the evacuation strategies can take into account the effect of emergency response activities within such buildings. A risk-based analysis can identify whether such egress studies would need to consider such hindrance factors for the entire evacuation time or only for a part of the evacuation time component.

7.6.13. Fire-Fighter Stair Travel Speed

The FBIM Table T provides six times associated with ascending and descending stairs for fire fighters including various pieces of equipment and associated rest breaks. Times T1 and T6 associated with ascending stairs with BA and equipment and rest breaks have been considered following a specific study undertaken with fire fighters in a high-rise building and comparison with the available international literature. This data is discussed separately in the FBIM section 0. This section considers the times associated with ascending stairs with the two types of hose used within the NZFS for internal fire-fighting hose, specifically high-pressure deliveries and the combination of 70 and 45 mm low-pressure deliveries as would be deployed when using a 'high-rise pack'. The times considered here assume that the hoses being carried or dragged are either dry or semi-charged but are connected to the appliance and being laid ready for immediate use. Section 0 should be referred to for times associated with carrying hose as part of a high-rise pack as shown below in Figure 46 and 41 or when water being supplied to a hose would be expected from an internal fire hydrant.

Insufficient data has been collected to date to draw any conclusions either specific to NZFS conditions or with the existing FBIM data. Considering that the data presented is on a 'per step' basis, and that there are only minor differences between the equipment carried, there is no reason to suggest any significant variance when considering the existing FBIM data. On this basis, and until sufficient data for NZFS fire fighters is collected and analysed, the data presented within the FBIM Table T are recommended for continued use. When using these values, the Australian 65 mm and 38 mm hoses should be considered the same as the NZFS 70 mm and 45 mm hoses, respectively. The FBIM data is presented in Table 23 and has been assessed within @Risk for the appropriate distributions to be used within a probabilistic analysis.

Table 23 FBIM Table T Fire-fighter stair travel speeds

Travel conditions	Time (s)				Sample size
	μ	σ	Minimum value	Maximum value	
T1 – ascend stairs In BA with equipment	0.94	0.45	0.25	2.10	73
T2 – ascend stairs with high pressure hose	0.48	0.28	0.09	1.21	33
T3 – ascend stairs with 65 mm diameter hose	0.71	0.31	0.15	1.40	34
T4 – ascend stairs with 38 mm diameter hose	0.77	0.27	0.40	1.40	33
T5 – descend stairs in BA	0.97	0.45	0.20	2.55	68
T6 – rest breaks (valid after 6 stair flights)	1.86	0.82	0.50	3.20	11

The following distributions using @Risk to re-evaluate the existing Australian FBIM data are suggested for these tasks:

T1 – lognormal $\mu = 1.2$, $\sigma = 0.48$, shift -0.24, min = 0.25, max = 2.1;

T2 – loglogistic $\Gamma = -0.098$, $\beta = 0.52$, $\alpha = 3.6$, min = 0.09, max = 1.21;

T3 – normal $\mu = 0.71$, $\sigma = 0.32$, min = 0.15, max = 1.4;

T4 – loglogistic $\Gamma = 0.26$, $\beta = 0.45$, $\alpha = 3.26$, min = 0.4, max = 1.4;

T5 – lognormal $\mu = 1.28$, $\sigma = 0.45$, shift -0.31, min = 0.2, max =2.55;

T6 – normal $\mu = 1.86$, $\sigma = 0.87$, min = 0.5, max = 3.2.

7.6.14. High-Rise Stair Climbing

7.6.14.1. Introduction

Fire-fighting operations within buildings often require fire fighters to climb stairs. Stair climbing while dressed in structural fire-fighting clothing and when carrying the necessary fire-fighting equipment such as hoses and BA increases the physiological effects and stress on fire fighters, which in turn increases the travel time vertically up stairs and the time to undertake fire-fighting tasks once the desired location is reached (3; 4).

Fire fighters use dedicated fire-fighting lifts in high-rise buildings if provided and when the height of the building dictates that climbing stairs will affect efficient fire fighting. However, if dedicated lifts are not available, because they have failed or the level of protection afforded to those lifts cannot be guaranteed, fire fighters may decide or be forced to use the stairs. Standard operational procedures also require that fire-fighting operations be based from the floor level below the location of the fire, so it is inevitable, even when lifts are used, that some degree of stair climbing in a multi-storey building will be required.

7.6.14.2. Existing Available Stair-Climbing Data

Section 7 of the FBIM manual (5) provides a single distribution for the stair travel speed in steps per second based on the number of steps for fire fighters wearing BA and carrying equipment. Distributions are also provided for the times taken to ascend stairs with both low-pressure and high-pressure delivery hoses connected to a fire appliance from ground level. These distributions are presented in Table 24. It is not known how many floors were climbed in each of the data sets collected and therefore what height limitations if any are applicable to the data. A distribution is also available to factor in rest breaks when using the distribution for building over six stories so it could be taken that this distribution is applicable to any height building.

Table 24 FBIM distributions given for vertical fire-fighter travel

Travel conditions	Steps/s				Sample size
	μ	σ	Min	Max	
Ascend stairs in BA with equipment	0.94	0.45	0.25	2.10	73
Ascend stairs with high pressure hose	0.48	0.28	0.09	1.21	33
Ascend stairs with 65 mm hose	0.71	0.31	0.15	1.4	34
Ascend stairs with 38 mm hose	0.77	0.27	0.4	1.4	33
Descend stairs in BA	0.97	0.45	0.20	2.55	68
Rest breaks (valid after 6 stair flights)	1.86	0.82	0.5	3.2	11

Various international studies have been undertaken on fire fighters climbing high-rise buildings. A UK study (3) assessed fire fighters climbing a 28-storey building wearing structural fire-fighting clothing referred to as Personal Protective Equipment (PPE), Extended Duration Breathing Apparatus (EDBA)[6] and carrying other equipment associated with high-rise fire-fighting operations. In this study, the lead group of four fire fighters carried equipment while wearing EDBA and PPE, while the second group of nine fire fighters were responsible for laying hose to make water available at the top of the stair. Tests were also repeated with the same groups of fire fighters wearing only PPE. This particular study also assessed the physiological condition of the fire fighters measuring heart rate, body core and skin temperatures as well as subjective assessments of exertion and thermal stress. As the fire fighters climbed in groups, average times are presented for each group concluding a time of 14.6 ± 1.3 minutes for the lead group wearing EDBA and carrying equipment, with the hose-laying group taking 10.5 ± 0.5 minutes. The times taken for the fire fighters to repeat the exercise while not wearing EDBA or carrying any equipment were found to be approximately half of that with the EDBA and equipment.

A study in Iceland (44) assessed four fire fighters wearing PPE, BA and carrying high-rise fire-fighting equipment within a 20-storey building. In these tests, fire fighters took between approximately six and eight minutes to reach the 20th floor. Average speeds of the linear distance travelled for the fire fighters' ascent were in the range of 0.37 m/s and 0.46 m/s for the total stair ascent slowing to 0.35 m/s and 0.45 m/s over the top five floors.

[6] For the purposes of this study there is no difference assumed between extended duration breathing apparatus and breathing apparatus that may occur between countries and that found with specific equipment.

The Mississauga Fire and Emergency Services department in Canada recently conducted a series of 'time trials' to determine the response times of fire fighters to high-rise buildings(76)(77). These trials compared fire-fighter response times in three separate residential high-rise buildings using stairs and lifts for access to the 5th, 10th, 15th and 20th floors. The crews carried typical high-rise fire fighting and medical equipment consisting of an apartment pack, medical bag, forcible entry tools, thermal imaging camera and defibrillator. The total weight carried by the crews including that of the PPE and BA is given below in Table 25.

Table 25 Typical PPE and equipment mass carried by Canadian fire crews

Item	Weight (kg)[7]
PPE, BA and apartment pack	41
Forcible entry kit	26
Medical bag (defibrillator)	35
Medical bag (oxygen)	31
Thermal imaging camera	25

Travel speed for individual fire crews were not reported, however average times for crews responding have been produced against those taken to access the floors using lifts. Table 26 shows the average travel time component from the lifts on the ground floor using either stairs or the lift to the designated floor. The reports indicate that crews slowed as they travelled to the upper floors and also noted that some crews used rest breaks on various floors as fatigue set in. The rest breaks were found to be necessary to ensure that crews conserved their energy so that they could undertake fire-fighting tasks effectively once they reached the designated floor. The crews were also asked how 'effective' they would be when reaching the designated floor. Seventy-five percent of crews reported that they would be prepared to 'effectively and efficiently' perform fire-fighting duties when they reached the designated floor.

[7] Equipment mass converted into metric from imperial values given (76)

Table 26 Comparison of vertical response times using lifts and stairs by Canadian fire crews

Floors	Average travel time from lift to designated floor using stairs (mins:secs)	Average time to designated floor using lift (mins:secs)
0	0:00	0:00
5	1:53	0:47
10	3:21	0:47
15	6:05	0:50
20	7:22	0:59

Figure 36 Compares the UK, Icelandic and Canadian data sets from the three studies.

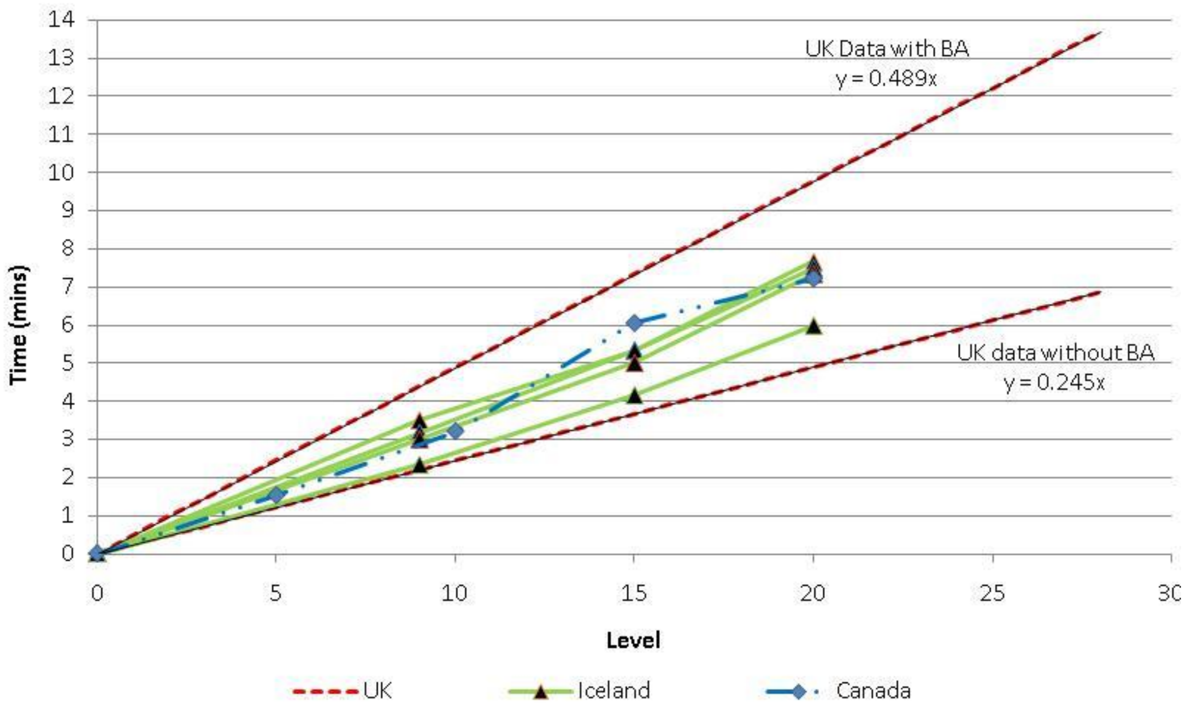


Figure 36 UK, Icelandic and Canadian stair climb data

A number of other studies are available that have factored in the speed of fire fighters climbing stairs. Kuligowski (78) suggests 0.35 m/s based on modified fire fighters' travel speeds taken from published data from people movement studies. This case study also used the New York fire department's rule of thumb of 60 s for each flight of stairs climbed. This later figure presenting a very conservative value when compared with directly measured times. However, it is unclear what activities are factored into this 60 s value, which could include a range of fire-fighting tasks such as laying hose and preparing to enter the compartment on fire.

It is important to note that all of the data presented above considered unobstructed flow. Real fire and emergency incidents have shown that fire fighters have great difficulty making entry into buildings and climbing stairs while occupants are making their escape. For example, a fire at the 52-storey Boston Prudential centre in the United States in 1986 penetrated one of the two egress stairs within the building preventing the use of this stair by either occupants or fire fighters. Due to the inability of the attending fire service to reach the fire floor and to undertake fire-fighting operations whilst occupants were descending down the single remaining stairs, operations were delayed for nearly an hour until all the occupants had escaped (74).

Similarly, the official reports into the emergency response operations that took place during the World Trade Center disaster (75) estimated that stair climbing rates for the emergency responders varied between 1.4 minutes per floor for emergency responders not wearing protective clothing or carrying equipment and 2 minutes per floor for those that were wearing protective clothing and carrying equipment, with an associated error of ±0.5 minutes per floor. These times also include for the counter flow effect of occupants escaping down the stairs which significantly hindered the fire fighters' time to ascend the stairs.

7.6.14.3. High-Rise Stair Climbing

Tests were conducted in a 28-storey Auckland office building to ascertain the travel time over the height of the building. A total of 52 fire fighters dressed in structural fire-fighting clothing were assessed. The fire fighters that took part in these tests represented a large cross-section of fire fighters including New Zealand Fire Service, career and volunteer fire fighters as well as a number of fire fighters from the Auckland Airport Emergency Service. Fire fighters with a range of fitness and experience levels took part including those who regularly trained and have undertaken many stair climbing events to those with no previous experience of climbing high-rise buildings in PPE. This broad cross-section of fire fighters is considered to be representative of the fitness of any particular individual and team of fire fighters who could be expected to have to undertake fire-fighting activities within a high-rise building.

Of the 52 climbers, all but six wore BA (not donned) with six climbers also carrying an additional mixture of typical high rise equipment including hoses, a branch and axe. The typical load associated with the clothing and equipment carried by the fire fighters ranged between 20 kg and 39 kg as shown in Table 27.

Table 27 Typical PPE and equipment mass carried by climbers

Item	Weight (kg)
Structural fire-fighting clothing	8.5
Breathing apparatus	11.5-14
45 mm hose pack	10.6
70 mm hose pack	16
Branch	1.2 – 4.13
Axe	2.8 – 5.7

The start of the climb was undertaken external to the building at level 0 with a measured horizontal distance of 48 m and 28 steps to reach the base of the stair tower at level 1. The stairwell within the building between levels 3 and 26 was 2.4 m wide and consisted of a single flight of stairs between each floor level with no mid floor landing. The travel distance between each flight of stairs measured 6.3 m and consisted of 19 steps. A typical floor level is shown in Figure 37. The stair treads and dimensions of the stairs from levels 1-3 and 26-28 altered between each of the levels to accommodate the geometry of the building at those levels.

Figure 37 Typical stair configuration

Typically, each stair and tread riser dimensions measured:

levels 0– 1 150 mm rise, 350 mm tread;
levels 1 – 25 190 mm rise, 300 mm tread;
levels 25 – 27 180 mm rise, 250 mm tread.

Times were measured at each fifth floor landing with additional times taken at the entrance to the stair tower at level 1 and at the top of the stair at level 28. Table 28 indicates the distance and number of steps between timing locations.

Table 28 Distance and number of steps between timing locations

Timing level	Distance (m)		Steps	
	Section	Cumulative	Section	Cumulative
0	0	0	0	0
1	40	40	28	28
5	47	87	79	107
10	47	134	95	202
15	47	181	95	297
20	47	228	95	392
25	47	275	95	487
28	47	321	59	546

There was no specific direction given to the climbers in terms of how they were expected to undertake the climb, i.e. to replicate emergency conditions. It was made clear from the outset that this exercise was not intended to be a race and that it was not a competitive event. Official timing of the climbers for other purposes did not take place which could have further encouraged a competitive environment. A brief was given to the climbers before the climb expressing the purpose of this data-gathering exercise. Before the climb started the climbers were also advised that they may be asked questions regarding their physical condition when they reached level 28 and also if they could provide a subjective assessment of their ability to continue and undertake further tasks including compartment fire-fighting operations.

Climbers formed 12 self-selected groups varying in size from 2 to 7 climbers although a number of individuals did not climb as part of any specific group. Each group was started approximately 30 s after each other which created a level of queuing at the entrance to the building at level 1. Of the 12 groups that started together, 6 arrived at level 28 with all members finishing within 30 s of each other indicating that these groups climbed as a team as would be expected in a fire scenario.

A number of competitive climbers monitored their individual times and undertook the climb at their fastest rate possible. These climbers times represented the quickest results and should therefore be taken as maximum possible rates of climb.

7.6.14.4. Results

Figure 38 presents the results for all of the 52 climbers to reach the 28th floor. The range of total times to complete the climb for all climbers was between 6.4 and 17.3 minutes, with 49 climbers reaching the top in under 15 minutes and 44 of the climbers completing the climb within 11.4 minutes. Considering the range of climbers and equipment carried, it is considered that the spread of data fits well with that available from overseas and within the expected ranges. The times for 49 of the fastest climbers fall within the ranges provided by the UK data with only three New Zealand climbers taking longer and three marginally faster than the UK times.

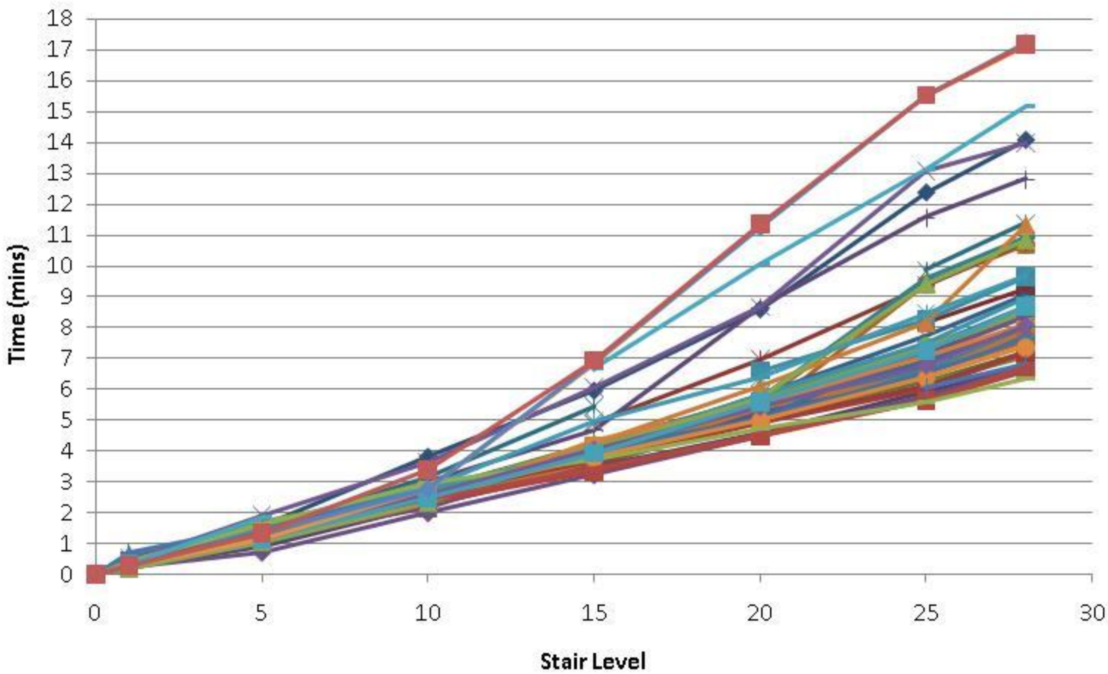


Figure 38 Time for 52 fire fighters to climb 28 floors

The times presented by the UK, Icelandic and Canadian studies are overlaid on Figure 39.

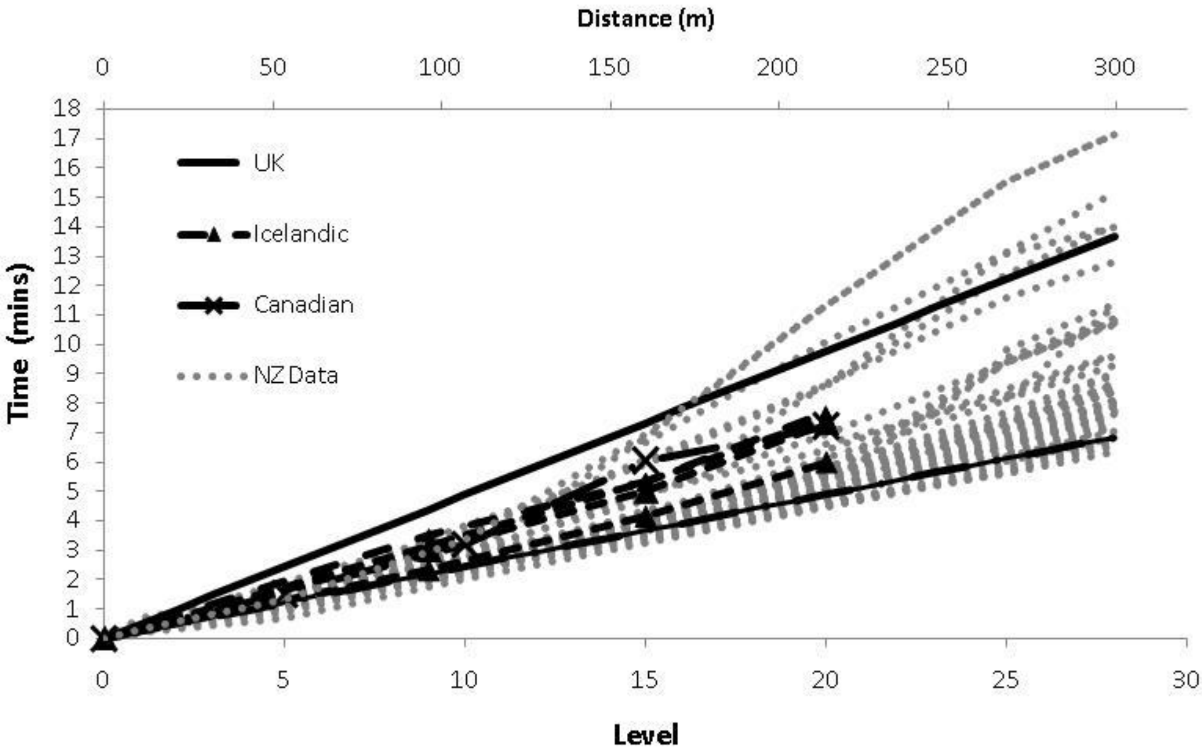


Figure 39 Overall times of 49 climbers compared with UK, Icelandic and Canadian data

The range of times from each of the studies is presented in Table 29 and given for the 20th and 28th floors for comparison.

Table 29 NZ Results compared with UK, Icelandic and Canadian data

Data set	Time to reach 20 floors (mins)	Time to reach 28 floors (mins)
NZ study	4.5–12. 8	6.4–17.3
UK with BA	9.8	10.5–14.6
UK without BA	4.9	5.3–7.3
Icelandic	6–8	8–10*
Canadian	7.22	10.5*

*Extrapolated

The speed of all the climbers based on the measured distance travelled within the stair is presented in Figure 40, which identifies the reduction in climbing speed up the first 15 flights of stairs and the relatively steady climbing speed obtained for the remaining 13 levels. As can be seen, the speeds obtained within the climb ranged from approximately 0.8 m/s to 1.6 m/s for the first 5 levels reducing to between 0.3 m/s and 0.8 m/s for the upper levels.

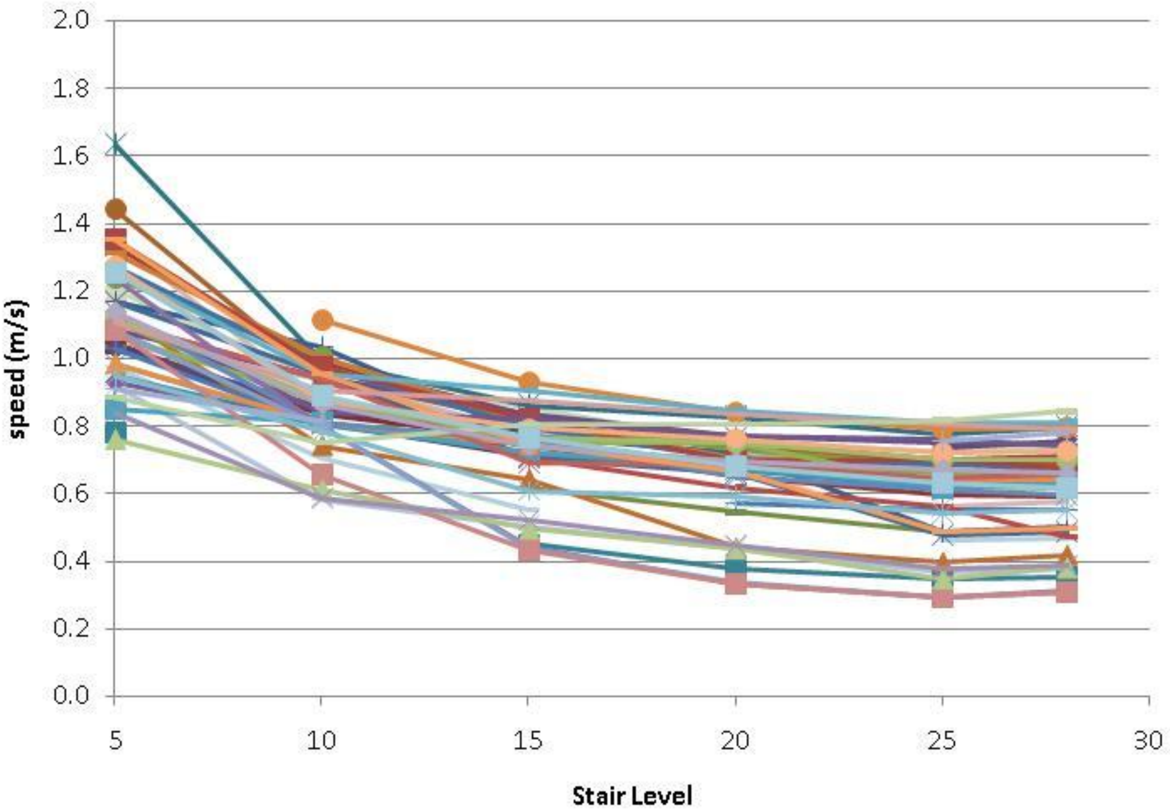


Figure 40 Average speed between each five floors

Figure 41 shows the step climbing rate and the initial low speed on a per step basis found over the first five levels. This reduced rate was found to be due to the stair arrangement which contained approximately half the number of steps per metre of the horizontal distance travelled than were present from level five onwards.

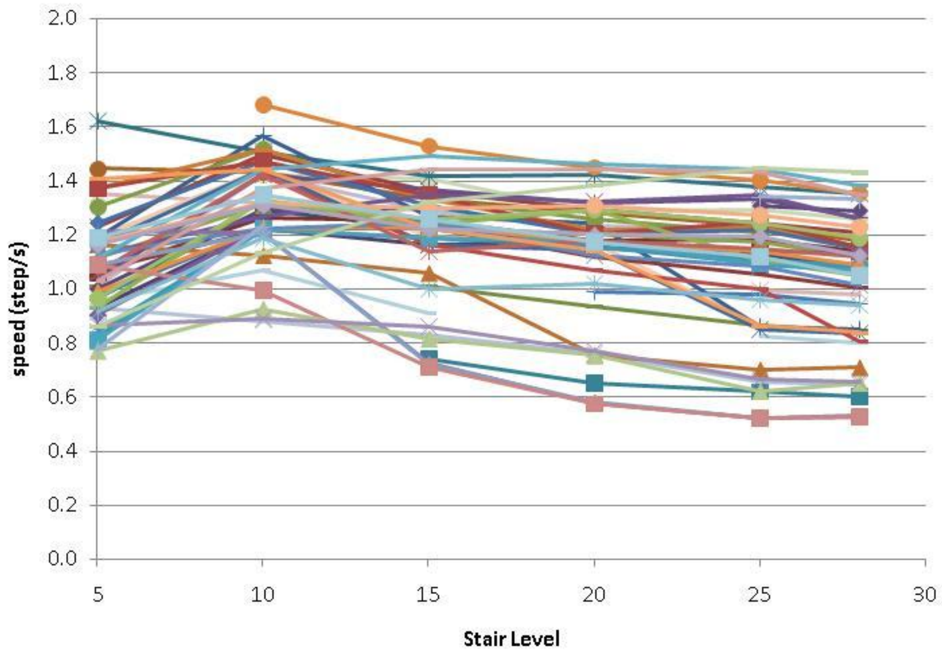


Figure 41 Step climbing rate between each five floors

The @Risk software (55) was used to fit distributions to the climbing speeds found at each 5th floor level. @Risk automatically ranks the fitted distributions according to the 'goodness of the fit' of which normal distributions were commonly highly ranked using the Kolmogorov–Smirinov fit statistic, which is appropriate for continuous data. The mean (μ), standard deviation (σ), maximum and minimum values representing each of the truncated distributions are given in Table 30 including the Kolmogorov–Smirinov fitting statistics. Each of these distributions is graphically shown in Figure 42. The shape of the distributions found are similar except at the 5th level which identifies a reduction in travel speed, considered to be caused by the queuing that occurred at the entry to the stairwell proper at level 1.

Table 30 Travel speed per section (m/s)

Level	Speed (m/s)				Kolmogorov–Smirinov fit statistic
	μ	σ	Minimum value	Maximum value	
Level 5	1.26	0.26	0.23	1.64	0.117
Level 10	0.85	0.14	0.29	1.11	0.181
Level 15	0.7	0.14	0.30	0.93	2.641
Level 20	0.65	0.14	0.30	0.85	0.241
Level 25	0.59	0.15	0.28	0.82	0.158
Level 28	0.6	0.15	0.29	0.84	0.142

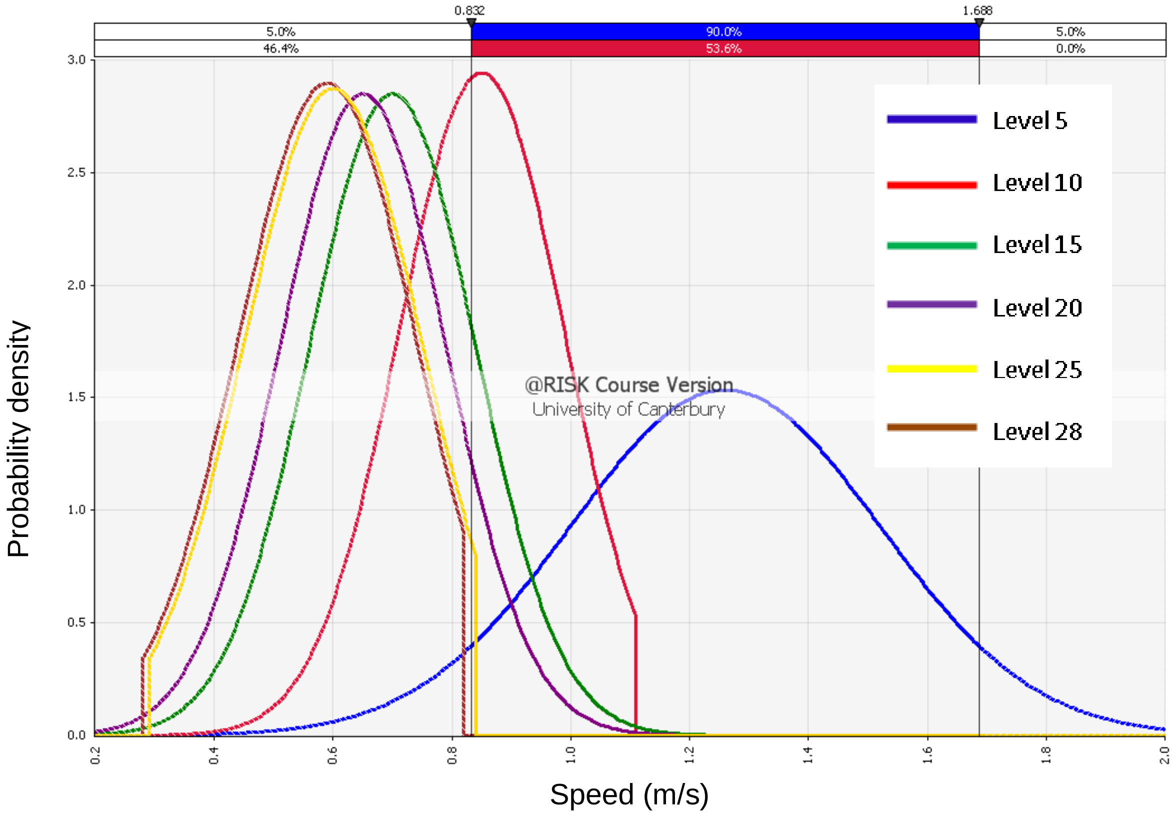


Figure 42 Fitted normal distributions for travel speed (m/s) at each five level section

Table 31 provides the values describing each of the normal distributions based on the step speed including the data from the FBIM manual (5). These distributions are shown in Figure 43 with the FBIM distribution shown identifying the far larger standard distribution of the data sets and a mean speed of μ = 0.94, slightly less than the means found within this data set. The larger standard deviation found with the FBIM data is possibly a function of the different configurations of stairs used, although information on the stair criteria used to collect the original FBIM sample data is not available. As the stair geometry was not a variable in this data set, this highlights a potential vulnerability in this data if applying it to a stair configuration that differs significantly from that used in this experiment. However, whilst some variables such as stair geometry may alter the climbing rates of individual fire fighters, the results found here when compared with those from similar research conducted overseas suggests that this is unlikely to be a major issue.

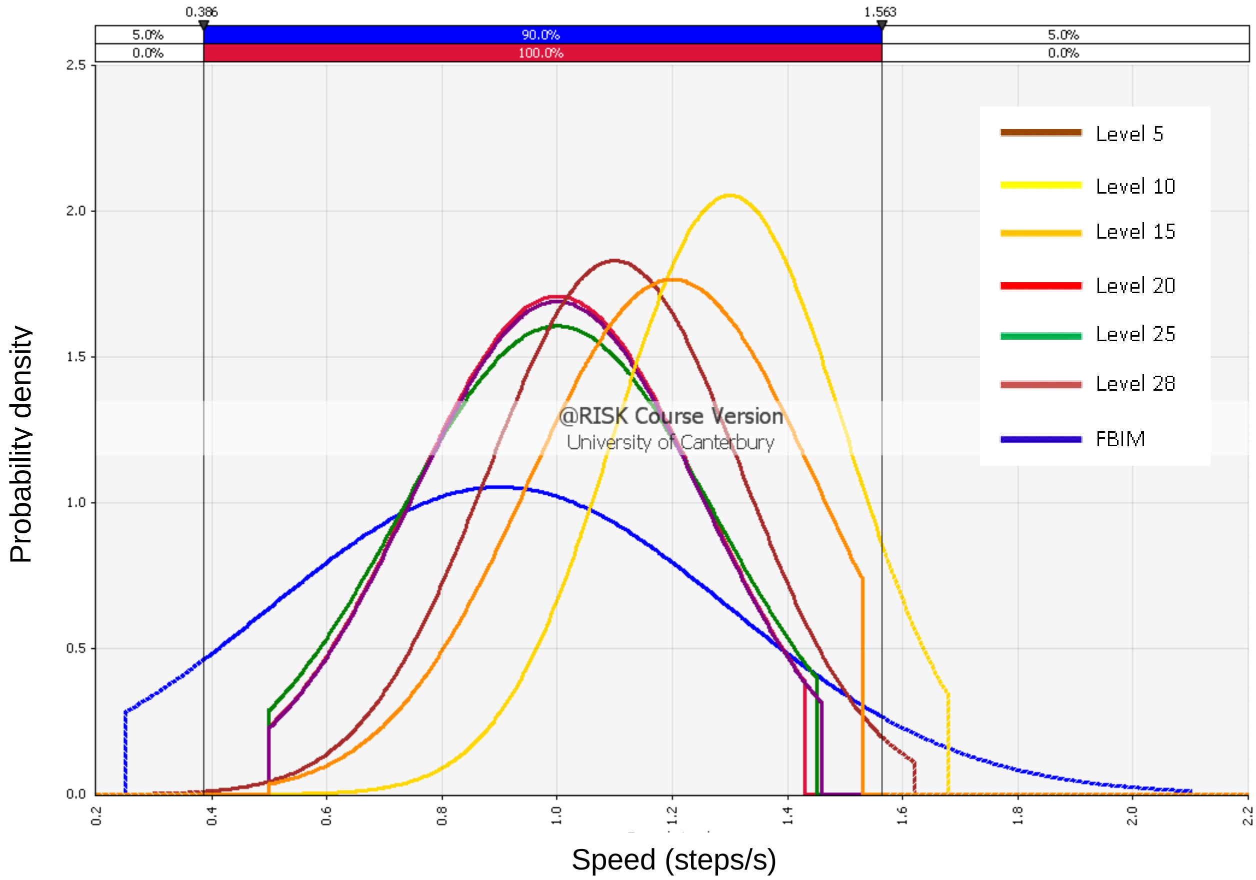


Figure 43 Fitted normal distributions for climbing rate (steps/s) at each five level section

Table 31 Climbing rate at each five level section (steps/s)

Level	Speed (steps/s)				Kolmogorov–Smirinov fit statistic
	μ	σ	Minimum value	Maximum value	
Level 5	1.1	0.2	0.27	1.62	0.088
Level 10	1.3	0.2	0.43	1.68	0.179
Level 15	1.2	0.25	0.50	1.53	0.227
Level 20	1.0	0.25	0.51	1.46	0.241
Level 25	1.0	0.27	0.49	1.45	0.158
Level 28	1.0	0.25	0.50	1.43	0.142
FBIM	0.94	0.45	0.25	2.1	N/A

The differences between the mean speeds found at each five level section are shown in Figure 44. The average climber speed per five level section falls as can be expected as a function of the number of flights of stairs climbed. However, when assessing the data on a per step basis, the average speed per step is shown to increase between levels 5 and 10 before it starts to decrease and level out in the later stages of the climb.

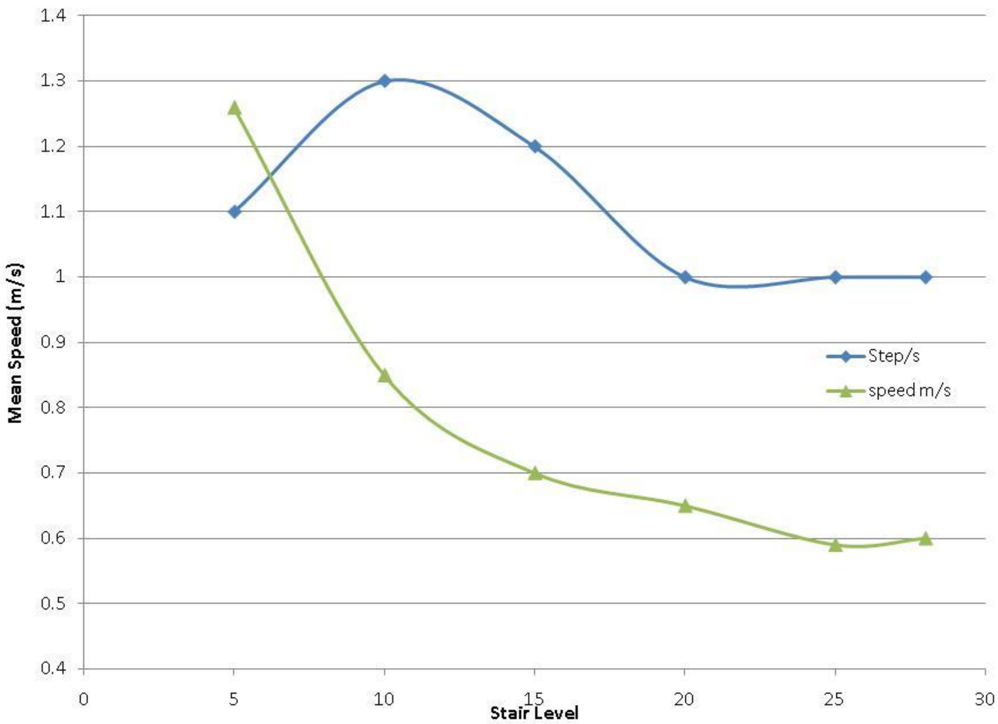


Figure 44 Comparison of means found between the two different reporting methods of steps per second and metres per second using the fitted normal distributions for the mean travel speed at each five level section

On a step-per-second basis, the returned average speed over the first five levels is skewed due to the fewer steps climbed to reach level five in this building relative to the distance travelled. This is not reflected within the speed graph based on the distance travelled as this included time for the climbers to travel between the sections of steps. On this basis, using distance rather than the number of steps is likely to be the best method where the number of steps required to be climbed is not in a typical stair configuration.

The mean speeds found at each 5 level section are shown in Figure 45 with a best-fit negative exponential equation fitted to the data set using the least squares method. This returned a sum of squares error of 0.00083342, such that:

$$s = 0.6 + 1.7 \times e^{(-0.2 \times L)} \qquad L \geq 5 \qquad [1]$$

Where *s* is the mean inclined speed in m/s and *L* is the stair level. For levels 5 and below it is suggested that a mean speed of 1.26 m/s be used with a standard deviation of 0.26 m/s as given in Table 30. The standard deviations varied little with the distributions found for each 5 level section from level 5 onwards so a standard deviation of 0.14 m/s for floors 10 to 20 and 0.15 m/s for buildings above 25 floor levels should be used to derive the distribution of speeds for fire fighters climbing stairs. No upper limitation on the use of this equation is proposed given that the travel speed found approaches a constant speed of 0.6 m/s as the number of levels increase. Although an upper travel speed of 0.6 m/s has not been validated, it would appear to provide a reasonable approximation of likely travel speeds that would be found above this level, not including any recovery periods or rest breaks that should also be factored into this type of analysis.

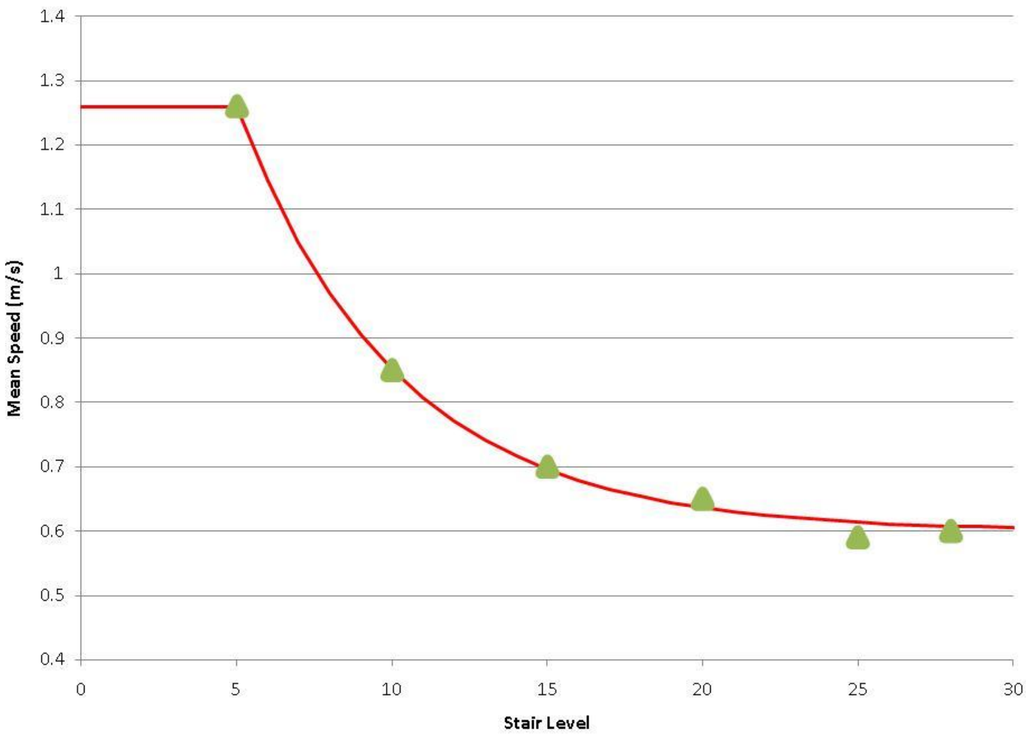


Figure 45 Mean speed using the fitted normal distributions at each 5 level section and suggested model

It should be noted that a number of factors affecting the climber's potential rate of travel were witnessed during this exercise. Queuing at the lower levels and on entry to the stair was noted, especially for the climbers placed at the end of the starting line. Congestion also possibly influenced climber times within the stair, especially on the lower levels as some climbers would have waited for convenient sections in the stairs, such as the landings, before overtaking other climbers. The stair consisted of an unusual configuration at the lower levels due to the entrance to the stair being on grade and no hindrance caused by the buildings occupants descending the stair was encountered by the climbers. Such factors could affect the climber's rate of stair ascent and could be considered with respect to the level of conservatism required for any analysis using this data.

7.6.14.5. Equipment Hindrance

The times from climbers carrying specific pieces of equipment were isolated from the majority of the climbers wearing only PPE and BA. These times were compared to investigate if the times could be distinguished from those not carrying any additional equipment and thus whether any specific hindrance factor could be established from this data. Nine climbers with and without BA have been specifically investigated, including the times of two climbers who only wore their PPE, did not wear BA or carry any additional equipment. Seven climbers carried either a 45 mm or 70 mm hose in bandolier fashion as shown in Figure 46. Although other equipment was carried by climbers, including an axe and a number of branches, this equipment was noted to be passed between climbers on their ascent, making isolation of specific individuals and the effect of this equipment on their time difficult to establish. This equipment is typical of that required to be carried by fire fighters as part of high-rise fire-fighting operations as shown in Figure 47; note that hoses can be carried either over the shoulder in a bandolier or coiled (Dutch rolled) in a back pack.

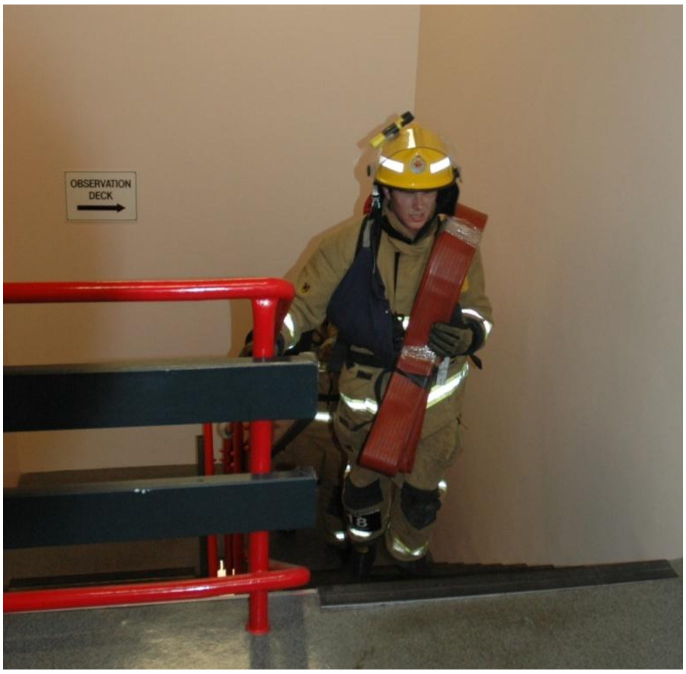


Figure 46 Climber wearing BA and carrying 70 mm Hose

Figure 47 Typical high rise equipment carried by two fire fighters (breathing apparatus not shown)

Figure 48 shows the spread of this data compared with that of the UK data with and without BA for comparison. As can be seen, there is no distinct difference between the climbers carrying the hoses, irrelevant of the hose diameter or weight. However, there is a distinct difference between those climbers wearing BA and those only carrying the hose. This data compares well with the UK data indicating that the addition of BA makes a significant difference to the climbers’ travel speed. As with the UK findings, the addition of BA in this study effectively doubled the time taken to climb the stairs. However, it is known that some of the fittest climbers including those who had trained for the climb were those that carried equipment and these times are reflected in these results. Further analysis would therefore be recommended before concluding that BA makes such a defined difference as indicated in this study.

A number of the climbers carrying equipment were asked about the effect they perceived this had on their ability to climb the stairs. Many of the climbers remarked that carrying equipment made the climb more difficult and slowed them down due to the difficulty in holding onto the handrail, as climbers used this as a climbing aid for support. Some of the climbers also remarked that they needed to change the hands carrying the equipment as they were using one hand to hold onto the handrail and the other to either hold the equipment or steady the hoses, for example, that were carried over their shoulders.

The conclusion and observations from this climb indicate that whilst the additional equipment would have provided a level of encumbrance, the weight and imbalance to the climbers when ascending the stairs was not the greatest factor in determining the climbers travel speeds. In this study, the fitness level of the individual climbers was observed to be the largest variation that affected the climbers' travel speed.

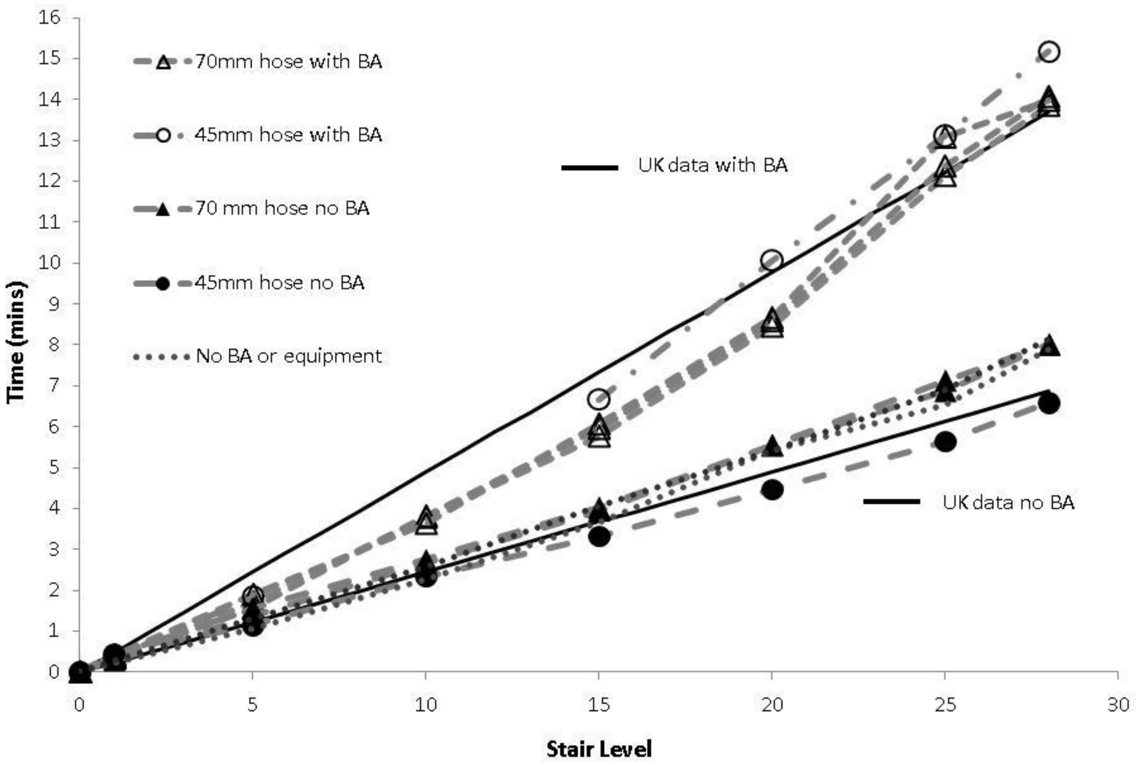


Figure 48 UK and NZ data for climbers carrying equipment

7.6.14.6. FBIM Data Comparison

Figure 49 compares the NZ data collected with the predicted times using the distributions given within the FBIM for a 28-storey building with 546 steps. The red curve depicts the NZ climb data versus the predicted distribution in green taken from the FBIM. The FBIM also provides a distribution for rest breaks that should be factored into any prediction once more than six flights of stairs are required to be climbed, this distribution is shown in purple. The results presented are based on a Monte-Carlo analysis using 100,000 iterations and the Latin Hypercube sampling method within @Risk (55).

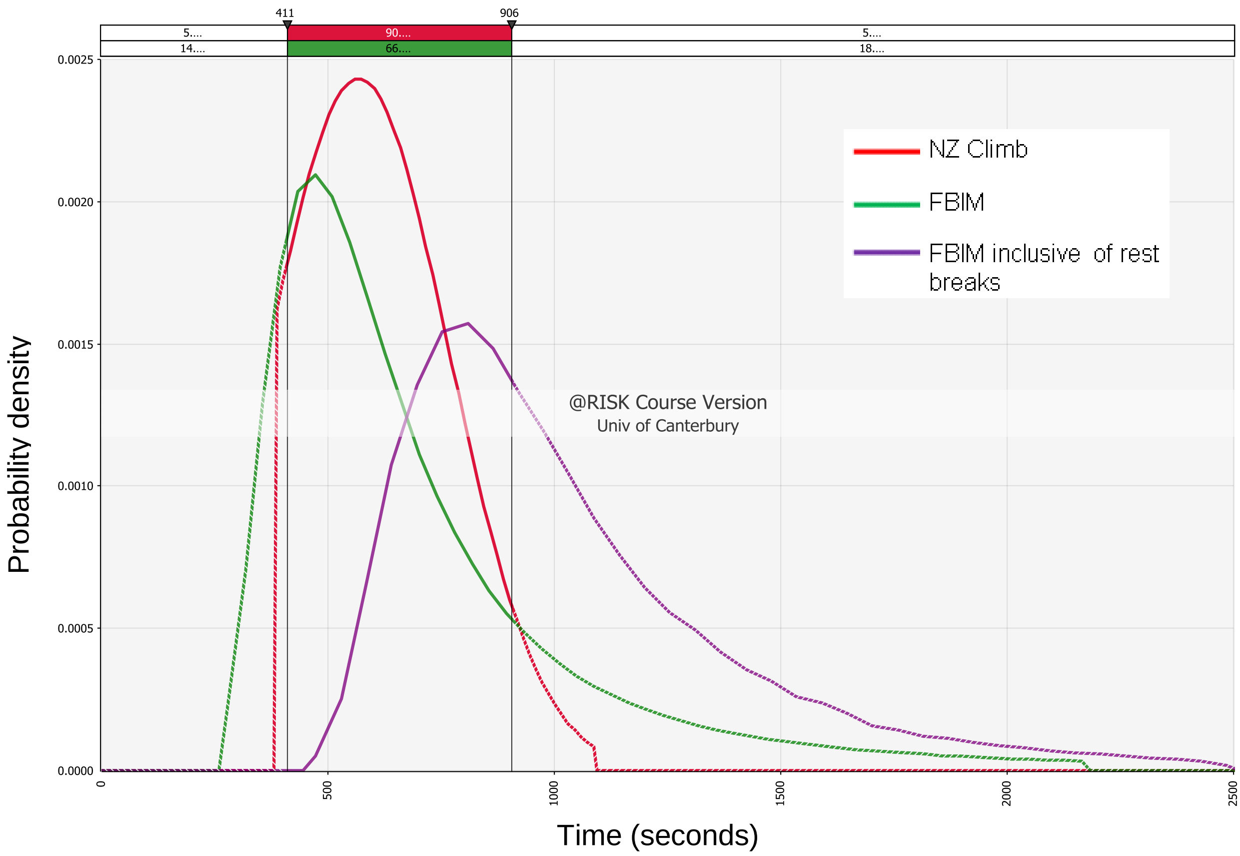


Figure 49 NZ fitted distributions of climber's times to climb 28 floors with predictions taken from the FBIM

Table 32 Distributions (time in seconds) based on NZ climb data and FBIM predictions

Fitted distributions	**Time (seconds)**			
	μ	**σ**	**Minimum value**	**Maximum value**
NZ climb	628	152	381	1095
FBIM	690	336	260	2184
FBIM with rest breaks	1028	373	445	3239

As can be seen, the returned mean FBIM predictions are within minutes of the NZ climb data and indicate a relatively good fit when the rest breaks are not factored into the prediction. This issue is further discussed in the following section.

The difference in the data collected in this study and that given in the FBIM is considered likely to be a product of the sample size and height of the buildings the data was collected in. A total of 73 samples were collected for the FBIM data but the heights of the buildings included in that study are not known. It is assumed that many of the FBIM data samples would have been drawn from relatively low-rise buildings in comparison to the 28-storey building in this study. A greater standard deviation would be expected considering the different building geometries as a variable in the FBIM data sets.

For the purposes of FBIM data, it was not expected that there would be any particular difference between the rates of fire fighters climbing stairs between countries. Whilst variations in equipment encumbrance (weight and size) could be a variable this is considered negligible to the variances expected between the fitness of individual fire fighters and the building geometry that could be expected in any particular emergency or FBIM analysis. Therefore, the data collected here should be applicable to any analysis of fire fighters climbing stairs and carrying equipment.

7.6.14.7. Recovery Period

At the finish of the climb a number of climbers were asked how exhausted they felt and how long they thought it would take before they would be able to undertake further tasks. Expected tasks would include entering a compartment on fire and starting fire-fighting operations. The range of subjective times suggested as recovery periods ranged from 0 to as long as 7 minutes. Whilst the responses were subjective it is clear that they reflected the climbing approach adopted by those questioned. Clearly, some climbers were extremely exhausted on reaching the 28th floor and would not be in a condition to take on further tasks until they had rested. Others, however, were considered to be in a relatively good condition and felt ready and confident in their ability to carry on working almost immediately.

Tomasson et al. (44) report times of 2.45 and 4 minutes, respectively, for two fire fighters to recover from climbing 20 flights of stairs before they felt ready to undertake compartment fire-fighting tasks. The World Trade Center emergency response operations report (75) considered that fatigue in fire fighters affecting their capability to undertake rescue operations becomes a factor after 12 flights of stairs. This report also provides fire-fighter witness statements that detail that rest breaks were as frequent as every 3 to 4 floors in certain cases.

Conclusions from the physiological studies performed on fire fighters climbing stairs in the UK (3) concluded that upon reaching the 28th floor the fire fighters would not be fit to commit to the fire compartment. This is concerning, as committing fire fighters to undertake further tasks, especially compartment fire fighting, when in such a condition could cause the fire fighters significant stress and overexertion. In the United States, of the 100-plus fire fighters that die on a yearly basis in the line of duty, approximately 45% of these fatalities are due to stress and overexertion (79). Therefore, fire fighters are recommended not to overexert themselves when undertaking activities prior to commencement of compartment fire-fighting activities. As the FBIM does not incorporate any rest breaks after undertaking specific tasks such as stair climbing and assumes that fire fighters will immediately commence the next task, any recovery periods need to be factored into the travel time or activity component. Therefore, the addition of the recovery periods noted at the finish of this climb need to be factored into the distributions when used for any analysis.

The FBIM provides for rest breaks to be factored into any assessment requiring travel in excess of six flights of stairs. As shown in Figure 49, the addition of rest breaks increases the prediction of the climbers' time significantly, with an increase in average time to reach the top level of 338 seconds for the FBIM data and 400 seconds for the NZ climb data.

Given that only anecdotal times were suggested from fire fighters, for the purposes of providing a distribution that can be factored into the analyses a uniform distribution time of 0–7 minutes is proposed. This distribution is shown diagrammatically in Figure 50 below:

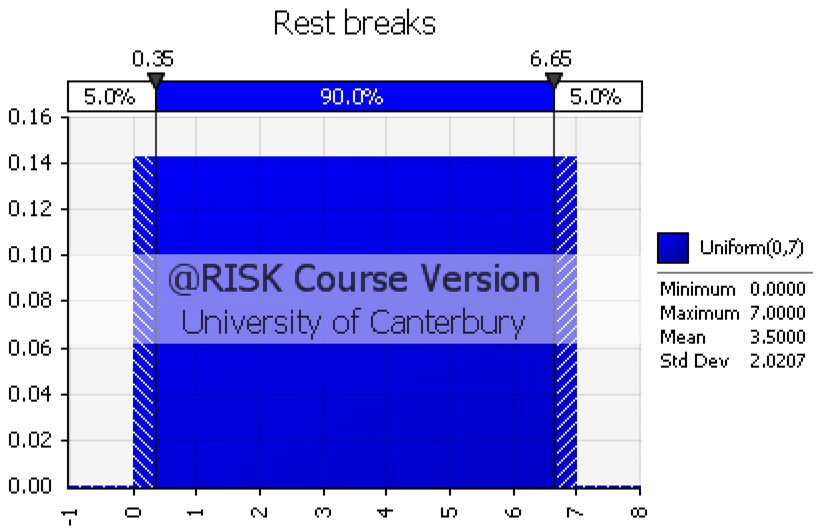


Figure 50 Proposed 0-7 minute uniform distribution for inclusion of rest breaks

Figure 51 below compares the NZ climb data inclusive of the proposed 0- to 7-minute uniform distribution for rest breaks. As can be seen, the NZ times in red compare relatively well with the FBIM-predicted times using the FBIM value for rest breaks with only 190 seconds between the mean values over the 28 floors. For simplicity and for assessments with fewer stairs than considered in this case studied, it is proposed that 60 seconds be added for every four flights climbed if a method using probability distributions is not being considered.

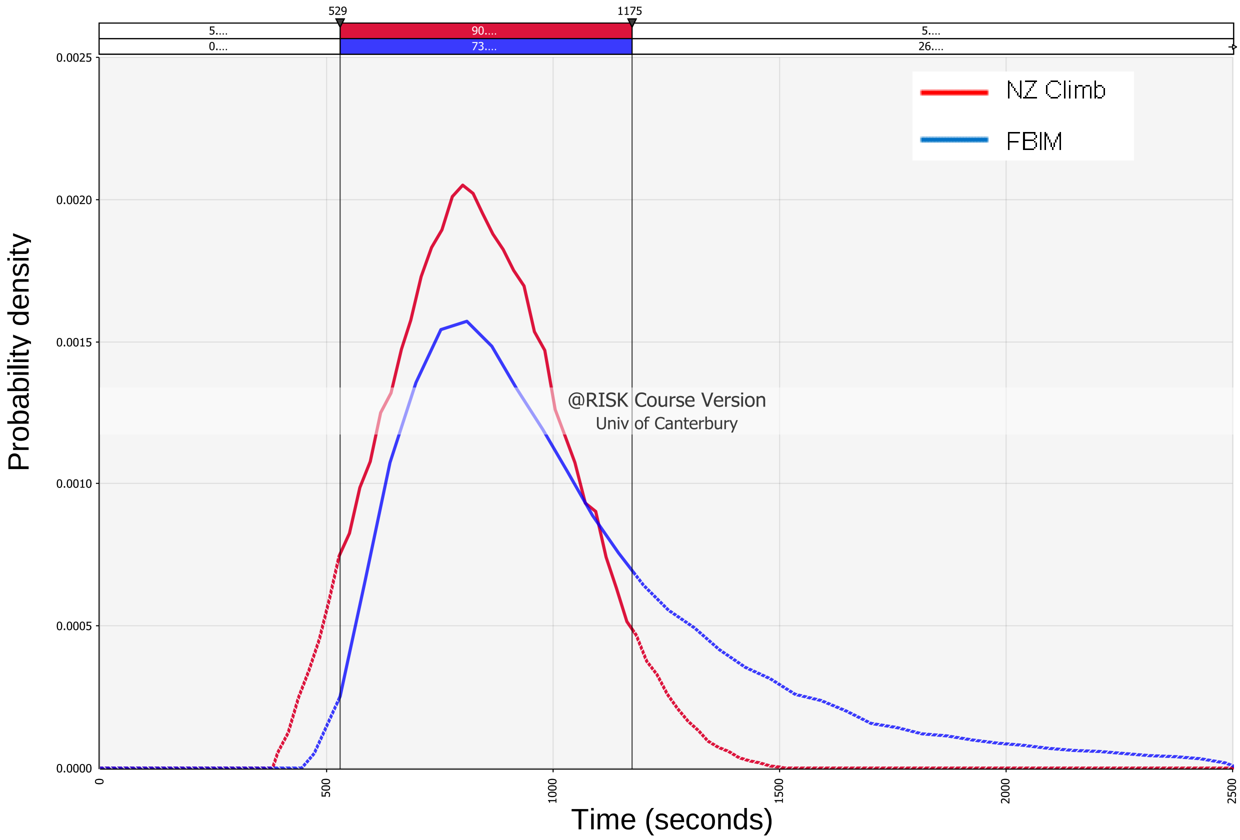


Figure 51 NZ results and FBIM predictions inclusive of rest breaks

Table 33 Calculated distributions (time in seconds) inclusive of rest breaks

Level	**Time (seconds)**			
	μ	**σ**	**Minimum value**	**Maximum value**
This study	838	194	382	1512
FBIM	1028	373	445	3239

7.6.15. Direct Comparison with the Icelandic Data

Figure 52 presents the results from a probabilistic assessment using the proposed model overlaid with the results from the study by Tómasson et al. (45). A Monte-Carlo analysis using 100,000 iterations and the Latin Hypercube sampling method within @Risk (55) returned the probability density curves considering a 20-storey building with a 178 m travel distance up the stairs. The Icelandic results provide slower average ascent speeds than found in this study but as can be seen, fall within the range predicted using the proposed model. The Icelandic times fall at the 86th and 95–96th percentiles of that predicted for the fastest times recorded to reach the 20th floor inclusive of the recovery period. Only four fire fighters' times were measured in the Icelandic study and Tómasson et al. also noted that their results were lower than results from previous tests. Of the 52 fire fighters measured in this study, five had slower average speeds than those in the Icelandic study, indicating the benefits of deriving distributions from larger data sets as presented here.

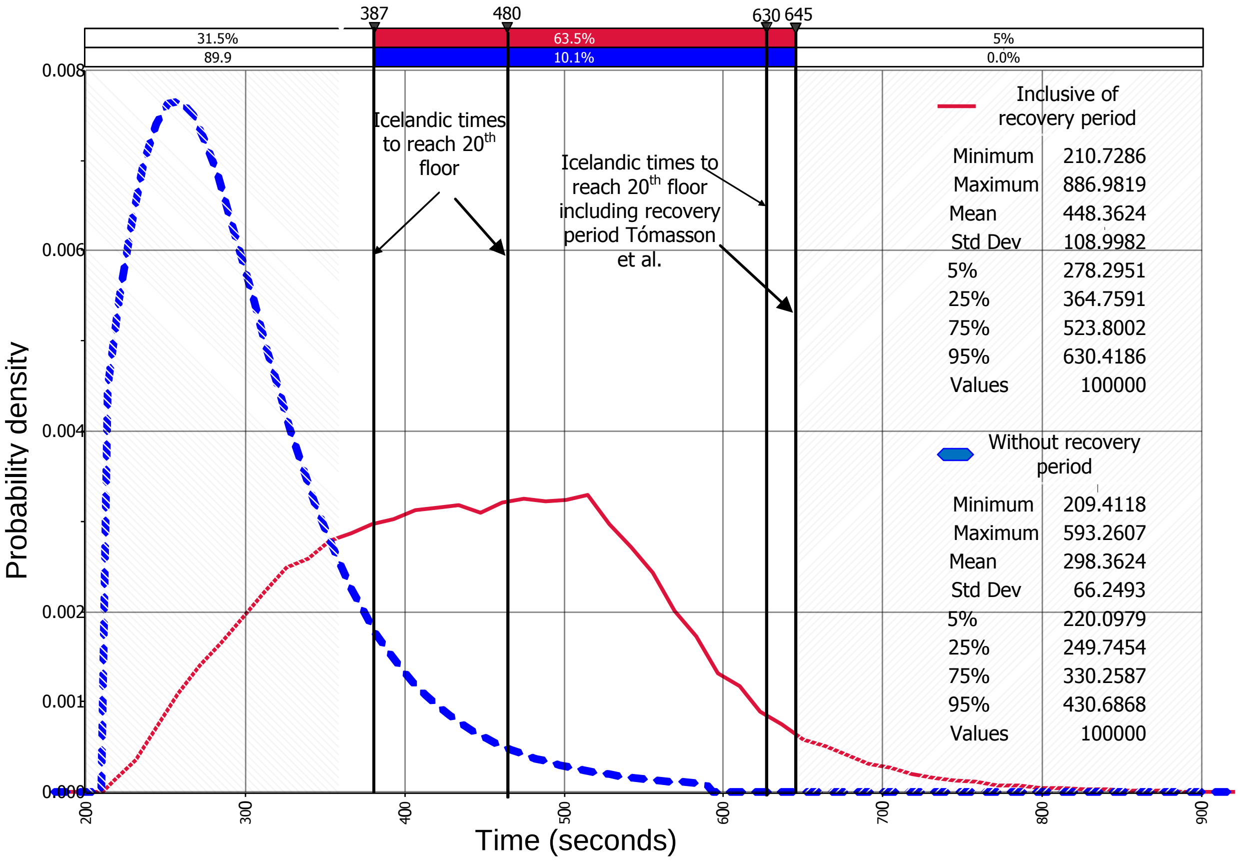


Figure 52 Comparison between Icelandic times and current study to climb 20 floors

7.6.15.1. Proposed FBIM Data

A common factor identified by a number of the climbers that presented a difficulty when climbing was the hindrance of the equipment being carried. Other than the additional weight that the equipment presented, carrying equipment also restricted the use of climbers' hands to hold onto a hand rail which aides climbing, especially when fatigue sets in. A number of climbers also moved the equipment and changed hands to allow the gripping of the hand rail on each side of the stair. However, equipment hindrance was not found to be the most significant factor affecting climbers' speed. Fitness levels of the individual fire fighters, climbing as a team and the individual's choice to climb the stair as fast as possible or to climb at a steady rate so that they were not totally exhausted when they reached the top appeared to be the main factors affecting climbers' speed.

For any analysis requiring consideration of fire fighters climbing tall buildings, the following distributions are proposed.

When the number of steps required to be climbed are known, the following values are recommended for each five flights of stairs (Table 34).

Table 34 Speed (steps/s) at each five level section

Level	Speed (Steps/s)			
	μ	σ	Minimum value	Maximum value
Levels 5–10	1.3	0.2	0.43	1.68
Levels 10–15	1.2	0.25	0.50	1.53
Level 20+	1	0.25	0.5	1.4

When the distance up the stairs is known, determine the mean travel speed from equation 1 where $L \geq 5$, or use the values presented in Table 35.

Table 35 Speed (m/s) at each five level section

Level	Speed (m/s)			
	μ	σ	Minimum value	Maximum value
Levels 0–5	1.26	0.26	0.23	1.64
Levels 5–10	0.85	0.14	0.29	1.11
Levels 10–15	0.7	0.14	0.30	0.93
Levels 15–20	0.65	0.14	0.30	0.85
Level 25+	0.59	0.15	0.28	0.82

To allow for rest breaks and recovery periods once fire fighters have reached the intended floor, a uniform distribution from 0 to X (where X is 60 seconds added for every four flights of stairs) is recommended, otherwise 60 seconds should be added for every four flights of stairs climbed if no distribution is desired.

7.6.16. Time to Position Appliance at Entrance

Table U within the FBIM provides a single value for the time associated with positioning an appliance at the entrance to the building at 2 m/s. There is no statistical data supporting this value so it is assumed that this value is recommended recognising that a nominal value is required to support the time taken for the appliance operators to establish the most suitable parking location with respect to the incident as it unfolds and depending on any predetermined tactics and immediate water supply or delivery needs. There is no reason to suggest that this nominal value needs revising or is not appropriate for NZFS aerial appliances considering that a nominal value is appropriate to take into account this specific task.

7.6.17. Time to Lay, Connect and Charge Hose

FBIM Table V considers the times associated with hose operations and the times taken to establish connected hoses between hydrants and appliances, appliances to branches, the appliance to sprinkler/hydrant inlet connections (referred to as booster connection in Australia) and the time taken to charge those hoses to a working pressure once the connection has been established.

Whilst data has been collected for all of these different hose operations, sufficient data of statistical relevance has been collected for comparison for only two of the hose operations. For task V1.1, the FBIM presents data collected from only three records for 90 mm hose. It can also be seen that the standard deviation for these three records is large, with significant difference between each data set found. Four data points have been collected using 90 mm feeder hose which are given below in Table 36. Whilst only four data sets have been established, these times are not only more closely matched but the mean speeds returned per section of hose are only slightly slower than those given within the FBIM data for the smaller diameter 65 mm hose, as would be expected. Therefore, the times found here are considered to be more appropriate than those currently presented within the FBIM data sets for 90 mm hoses supplying water from a hydrant to an appliance, data set V1.1.

The other data set with enough data to form a comparison is that considering tee times taken to remove 70 mm delivery hose and connect to a branch, FBIM data set V 2.1. Considering the 25 m length of 70 mm diameter delivery hose 11, data samples have been collected with the most suitable fitting distribution shown in Figure 53 compared to that with

FBIM data for 30 m long, 65 mm diameter hose. Considering the number of data samples collected compared with the 82 data sets given within the FBIM, the distribution returned is as expected with a lower standard deviation and reduced average time per section of hose. Given that the largest variable between the relevant hoses is the length, it would be expected that the average time to lay and connect a 25 m length of hose would be on average faster than laying a 30 m length. Whilst the diameters are slightly different, this would be expected to be negligible as the results suggest. However, the number of data sets collected so far is not considered large enough to recommend a distribution for FBIM analysis purposes as it is unlikely to represent sufficient variables that could be expected on a fire ground. The distribution is represented by only 43% of the FBIM data suggesting that a larger standard deviation would be found if enough samples were collected under more variable conditions.

Given the above, the FBIM distributions for hose are recommended to be used for NZFS purposes except for data set V1.1 for which the distribution found within this data set is recommended for use within an FBIM analysis.

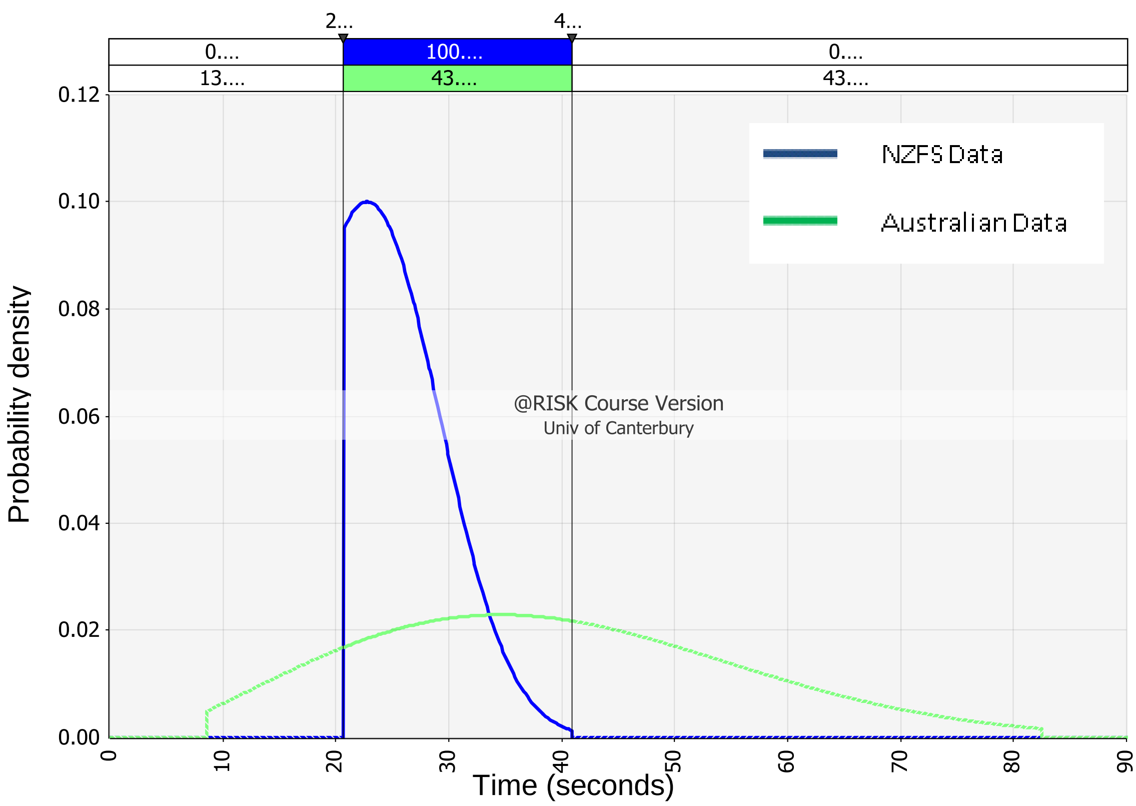


Figure 53 Australian and NZFS distributions found for the times taken to remove delivery hose and connect to a branch (per section of hose)

Table 36 FBIM Table V with NZFS data for hose operations

Hose connection conditions (all times per 25/30 m hose length)	Hose ϕ (mm)	Time (s)				Sample size
		μ	σ	Minimum value	Maximum value	
NZ data						
V1.1 – remove, connect & charge hose from hydrant to appliance	90	84.8	11.5	67	99	4
V2.1 – remove & connect hose from appliance to branch	70	23.26	5.88	12.67	33	11
Australian FBIM data						
V1 – remove, connect & charge hose from hydrant to appliance	90	144.7	90.2	50	266	3
	65	60.4	30.2	14	154.4	156
V2 – remove & connect hose from appliance to branch	65	39.4	17.4	6	80	82
	38	33.3	15.4	2	70.7	36
V3 – remove & connect hose from appliance to booster connections	65	45.3	17.1	17.5	80	39
V4 – charge delivery hose from appliance	65	20.3	13.2	2.5	80	119
	38	18.4	10.2	6	45	37
V5 – connect hose to boosted hydrant and charge	65	59.6	37.9	15	163	52
	38	40.9	17.8	14	90	28

The following distributions using @Risk to re-evaluate the Australian data suggests the following distributions for these tasks:

V1.1 – normal μ = 84.8, σ = 11.5, min = 67, max = 99;

V1.2 – lognorm μ = 89, σ = 31, shift −28.5, min = 14, max = 154;

V2.1 – Weibull α = 2.25, β = 41.7, shift 2.5, min = 6, max = 80;

V2.2 – normal μ = 33.3, σ = 15.6, min = 2, max = 70.7;

V3 – lognorm μ = 50.8, σ = 18, shift -5.5, min = 17.5, max = 80;

V4.1 – gamma α = 2.3, β = 8.1, shift 1.5, min = 2.5, max = 80;

V4.2 – loglogistic Γ = 2.97, β = 12.8, α = 2.6, min = 6, max = 45;

V5.1 – loglogistic Γ = 10.7, β = 36.8, α = 1.97, min = 15, max = 163;

V5.2 – normal μ = 40.9, σ = 18.1, min = 14, max = 90.

7.6.18. Time to Search for External Water Source

FBIM Table W provides for an additional time component to be factored into the FBIM assessment when the location of the water source is not immediately adjacent to the building and fire service main attendance and parking location. This time should be included on top of the time taken to travel between the hydrant and appliance.

Table 37 FBIM Table W Time to search for external water source

External search for street main hydrant	Time (s)
Where street hydrant is < 30 m from appliance set up	additional 30 s
Where street hydrant is > 30 m < 60 m from appliance set up	additional 90 s
Where street hydrant is > 60 m from appliance set up	additional 180 s

The times associated with searching for external fire-fighting facilities that are not immediately apparent or located adjacent to fire appliance access locations has been witnessed to be highly dependent on the fire fighters' local knowledge of the facility and surrounding facilities. Fire fighters undertake familiarisation visits to buildings located close to their fire station as part of general operational emergency planning arrangements. Local knowledge of risks and preplanning activities provide significant learning opportunities, information dissemination between crews and increases the efficiency of operational tasks such as establishing water supplies in the event of emergencies. However, such local knowledge of buildings cannot readily be relied upon as it is heavily dependent on individual's knowledge and the assumption that the fire fighters with such knowledge will be the first on the scene. Even when the first appliance arrives at an emergency from the closest located fire station, there is a possibility that the first arriving fire fighters may have no knowledge of the building or local fire-fighting infrastructure.

The importance of local knowledge has been demonstrated in the two independent fire ground field experiments reported in Section 8.5, where two different crews replicated the same incident within the same building. In these two exercises, the time taken to locate external street hydrants was shown to be dependent on the fire fighters' level of knowledge of the site. The first exercise identified the issues encountered by fire-fighting crews trying to establish water supplies from a fire hydrant to an appliance without prior knowledge of the location of the hydrant. In this exercise, it took a fire fighter approximately 50 seconds to locate the street hydrant located 57 m from the fire appliance including travel time with a standpipe. Once located, this fire fighter returned to the appliance for the hose and returned to the hydrant to connect it to the appliance. During the repeated exercise where the fire fighter had prior knowledge of the location of the hydrant, the fire fighter was able to take a standpipe, feeder hose and necessary tools directly to the hydrant in one go to enable full connection and the establishment of water to the appliance within a total of 67 seconds. Due to the repeated trips to the hydrant in the first exercise, it took nearly two minutes more to supply the fire appliance with water than in the second exercise.

The additional times given in the FBIM to take into account the extended distances between external hydrants and the fire appliance access and final parking locations appear to be appropriate from the exercises witnessed.

7.6.19. Time to Obtain Static Water

FBIM Table X provides the various times associated with the tasks required for fire fighters to establish water to an appliance, either from an open water source or tanked supply. These times include positioning of the appliance and the making up of and securing of hard suction hose. The time taken to position a fire appliance when obtaining water from a tanked or static source will depend upon the ease at which an appliance can make access to the source and identification of the location of the supply. For tanked supplies, clear and obvious signage should be provided identifying the location of any tank with appropriate access and hard standing in close proximity to the tank outlets. For open water sources, appliance access and positioning is critical due to the relatively short length of hard suction hose carried on an appliance. As only a maximum of 10 m of hard suction hose is carried on an NZFS fire appliance, access to the tank outlets or water source will need to be well within 10 m from the position of the fire appliance inlets (typically on the off side of the appliance) minus the height of the source. The NZFS Fire-fighting Water Supplies Code of Practice, PAS NZS 4509 (80) provides details regarding fire-fighting water supplies and relevant access requirements to water supplies such as open and static water sources to ensure that they meet fire-fighters operational requirements. As addressed above, local knowledge can be crucial to minimise times associated with locating such facilities. However, as this cannot be guaranteed, appropriate signage should be provided to help locate such supplies.

To date, three separate exercises have been conducted to determine the times taken to establish water supply to an appliance from an open water source. No suitable tanked supplies were found to undertake the FBIM exercises. Whilst suction hose can vary slightly in diameter, the main difference found between Australian and NZFS suction hose is the length, with only 2.5 m lengths used as standard within the NZFS compared with 3 m lengths used as standard within Australia. Whilst statistically the number of records for this study is not significant, the returned average values for each task compares relatively well, except for the time taken to connect the suction hose to the appliance. Table 38 shows the data contained within the FBIM manual with the average values from the three NZFS data sets given in brackets.

Table 38 FBIM Table X times to obtain static water (with NZFS data in brackets)

Activity	Time (s)				Sample size
	μ	σ	Minimum value	Maximum value	
X1 – position appliance (m/s)	1.1 (0.8)	0.5	0.16	2.42	84
X2 – remove suction hose and connect to tank (seconds/3 m length of suction hose)	18.6 (66)	7.5	3	37.5	85
X3 – prime suction hose from tank (s)	23.5 (N/A)	15.3	7	70	39
X4 – secure suction for open water drop (s)	97.7 (110)	54.4	23	265	49
X5 – lower suction hose to open water and prime (s)	60.7 (64)	37.9	10	180	48

The following distributions have been derived using @Risk to re-evaluate the Australian data for these tasks:

X1 – lognormal $\mu = 3.2$, $\sigma = 0.5$, shift -2.1, min = 0.16, max = 2.4;

X2 – normal $\mu = 18.6$, $\sigma = 7.6$, min = 3, max = 37.5;

X3 – loglogistic $\Gamma = 6$, $\beta = 12$, $\alpha = 1.6$, min = 7, max = 70;

X4 – beta general $\alpha_1 = 1.1$, $\alpha_2 = 3.1$, min = 23, max = 265;

X5 – lognormal $\mu = 63.9$, $\sigma = 38.3$, shift -3.3, min = 10, max = 180.

7.6.20. Times for Search and Rescue

Where fire fighters are required to undertake search and rescue activities within buildings, the time associated with these tasks will be heavily dependent on the level of visibility present and the size and complexity of the compartment. There are two types of search procedures undertaken at an incident identified as the primary and secondary search. Search and rescue activities will be undertaken in accordance with NZFS standard operational procedures, which requires all rescue activities to involve a primary search. This requires rescuers, working in teams of two or more, to search the perimeter of the room first, followed by a sweep of the centre of the floor. These methods are employed to ensure that all areas of the room are searched considering that visibility levels can be expected to be zero and that fire fighters will be reliant on what they can touch and feel as they move through a room in which the layout and sometimes size may not be known. When conducting a primary search in a fire situation, fire fighters will take a hose line with them to provide protection to themselves and any casualties as well as providing a means of identifying and protecting their escape route and allowing them to conduct an attack on the fire if required. A typical search and rescue pattern is shown below as given in the NZFS training manual (81).

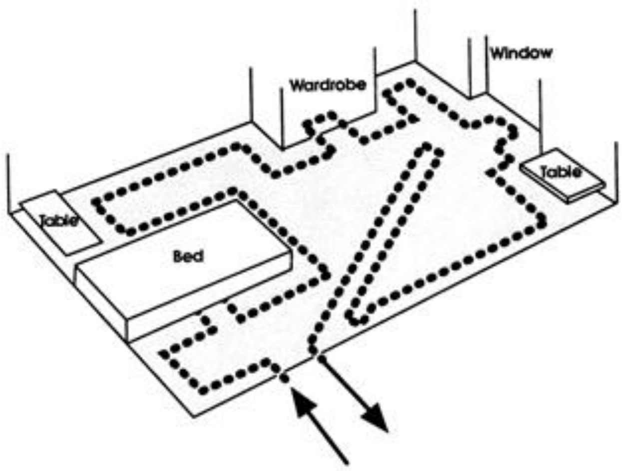


Figure 54 NZFS methodology for the correct method for searching a room

The secondary search occurs once the situation is under control and the fire has been contained, and is undertaken to confirm the presence of casualties and to account for all occupants. When estimating the time taken to undertake a primary or secondary search, the operational capabilities and limitations of fire-fighters needs to be recognised to ensure that unrealistic expectations are not factored in to any design. As well as being limited by the duration of BA, the physiological and psychological demands on fire fighters, especially under thermal stress, needs to be recognised. UK research has shown that the depth of a compartment that can be safely negotiated from a place of relative safety such as a stair may be as little as 32 m. Also, research into the operational capabilities of fire fighters wearing PPE and BA in other conditions such as tunnels has identified that the safe depth of penetration is between 100 and 300 m depending on the tasks expected of fire fighters, even when under no thermal stress from a fire (82 p. 485).

There are two main types of BA set used within the NZFS, the Sabre Centurion and Dräger PA 94 Plus set using either steel, hoop-wrapped fibre-reinforced plastic or fully composite cylinders. Generally, BA sets have a standard duration of approximately 30 minutes. However, the actual duration is completely dependent upon the consumption of the wearer and their work rate. Durations of as little as 10 minutes could be expected if fire fighters are working at their maximum rate as would be expected during search and rescue or compartment fire-fighting activities.

No data to date has been recorded to establish the times associated with search and rescue activities. The simulation of a search and rescue of real persons was a major part of two exercises conducted as part of this research as discussed in section 8.5. However, due to the theatrical smoke released during these exercises and the reduced visibility conditions that resulted, it was impossible to record the travel times within the searched compartments and any quantifiable data relating to travel times within different visibility conditions. Whilst the times taken to remove the occupants from the buildings were recorded and an attempt to follow the fire fighters while undertaking the searches was made, the distances travelled and times associated with searching specific parts of the building were difficult to establish.

For the purposes of establishing appropriate FBIM data, it is necessary to investigate the times associated with fire-fighter travel under different visibility conditions. To undertake this successfully the use of theatrical or pyrotechnic smoke is considered undesirable as it does not produce measurable or uniform conditions within compartments representative of those found during real fires or that are easy to quantify for the purposes of this research. On this basis, it is recommend that for future research fire fighters are provided with BA masks that replicate known levels of smoke visibility as are currently available for training purposes. This way it would be possible to quantify the relationship between visibility and the speed at which fire fighters undertake search and rescues operations within smoke-affected buildings.

FBIM Table Y provides two values for the time taken to conduct a perimeter search and for the time taken to remove or rescue an occupant. As no data has been established for these times for NZFS fire fighters, the FBIM data is required to be used. The associated speeds at which fire fighters can search a room or remove a person during rescue operations are unlikely to be any different between different brigades considering the variables that would affect this type of task. The main variables are likely to be the nature of the search required given the conditions faced by the fire fighters as well as the condition of the area requiring search and other variables such as the experience of the individual fire fighters and their relative fitness given the operating environment.

Table 39 FBIM Table Y times for search and rescue

Activity	Time (s)				Sample size
	μ	σ	Minimum value	Maximum value	
Y1 – secondary search (m^2/s)	0.16	0.05	0.07	0.3	28
Y2 – remove/rescue person (m/s)	0.05	0.03	0.01	0.13	27

The following distributions using @Risk to re-evaluate the Australian data are suggested for these tasks:

Y1 – normal $\mu = 0.16$, $\sigma = 0.05$, min = 0.07, max = 0.3;

Y2 – lognormal $\mu = 0.05$, $\sigma = 0.03$, shift −0.007, min = 0.01, max = 0.13.

7.7. Time to Set up Aerial Equipment

Australian and New Zealand Fire Services use a variety of aerial appliances to perform various fire suppression and rescue activities. The use of aerial appliances during any incident will be dependent on the specific type of appliance available as not all aerial appliances can perform the same tasks. As specialist appliances, aerial appliances are generally only available in the major urban cities or are located due to specific risks. Consultation with the relevant fire brigades should be made to determine the appliance type and availability. The type of operations which aerial appliances typically undertake includes:

- elevated water supply;
- water tower and water relay;
- continuous rescue (e.g. using a ladder);

- cyclic victim removal (e.g. using a basket);
- crane (fire/rescue-related incidents);
- equipment elevation;
- observation tower.

There are four generic types of aerial appliances typically used by fire services as given within the AFAC Aerial Code of Practice (83).

- **Telescopic Turntable Ladder (TTL) apparatus** is defined by a number of incorporated telescopic ladder sections.
- **Telescopic Boom (TB) apparatus** is defined by having a number of incorporated telescopic booms (FBIM uses teleboom).
- **Articulated Boom (AB) apparatus** is defined by having one or more joints which provide boom articulation, without telescopic capability.
- **Articulated Telescopic (AT) apparatus** is defined by having a combination of telescopic and articulating booms.

The NZFS operates a range of different aerial appliances across its fleet and has recently begun standardising the type and availability of its aerial appliances. Timing exercises using three different aerial appliances have been undertaken to establish the times, manpower and issues associated with setting up and operating aerial appliances during emergency incidents. This includes exercises undertaken on flat ground away from buildings and in close proximity to buildings on an incline.

The following aerial appliances were used for these purposes.

- **Bronto Skylift F32 RLH.** Type 5 articulated telescopic ladder/platform which is now being standardised across the NZFS fleet.
- **Aerialscope.** Type 6, 23 m articulated boom with platform.
- **Thibault** Type 6, 30 m telescopic turntable ladder.

Table 40 provides the data for aerial appliances given within the FBIM manual which is shown diagrammatically assuming a normal distribution in Figure 55. As can be seen, the distributions vary widely with set up times as low as 35 seconds increasing to 607 seconds for the turntable ladder. It is not known what specific appliances were used to collect this data or the conditions under which the data was collected. From the information collected so far from using NZFS aerial appliances it is apparent that significant differences may apply to different makes of aerial appliances irrespective of their type.

Table 40 FBIM Table Z times to set up aerial equipment

Aerial appliance set-up	Appliance type	Time (s)				Sample size
		μ	σ	Minimum value	Maximum value	
Z1 – position aerial appliance (m/s)		0.54	0.32			
Z2.1 – set up appliance in preparation for use (s):	Teleboom	56.6	17.6	40	105	20
Z2.2	TT ladder	292.0	222.1	35	607	6
Z2.3	Platform	145.9	59.4	35	210	33
Z3 – conduct safety procedures (s)		62.9	33.7			
Z4.1 – elevate and manoeuvre appliance 180° (m/s):	Teleboom	0.11	0.04	0.02	0.19	22
Z4.2	TT ladder	0.18	0.09	0.09	0.35	7
Z4.3	Platform	0.12	0.05	0.04	0.22	34
Z5 – charge monitor (s)		31.5	25.0	6	130	57

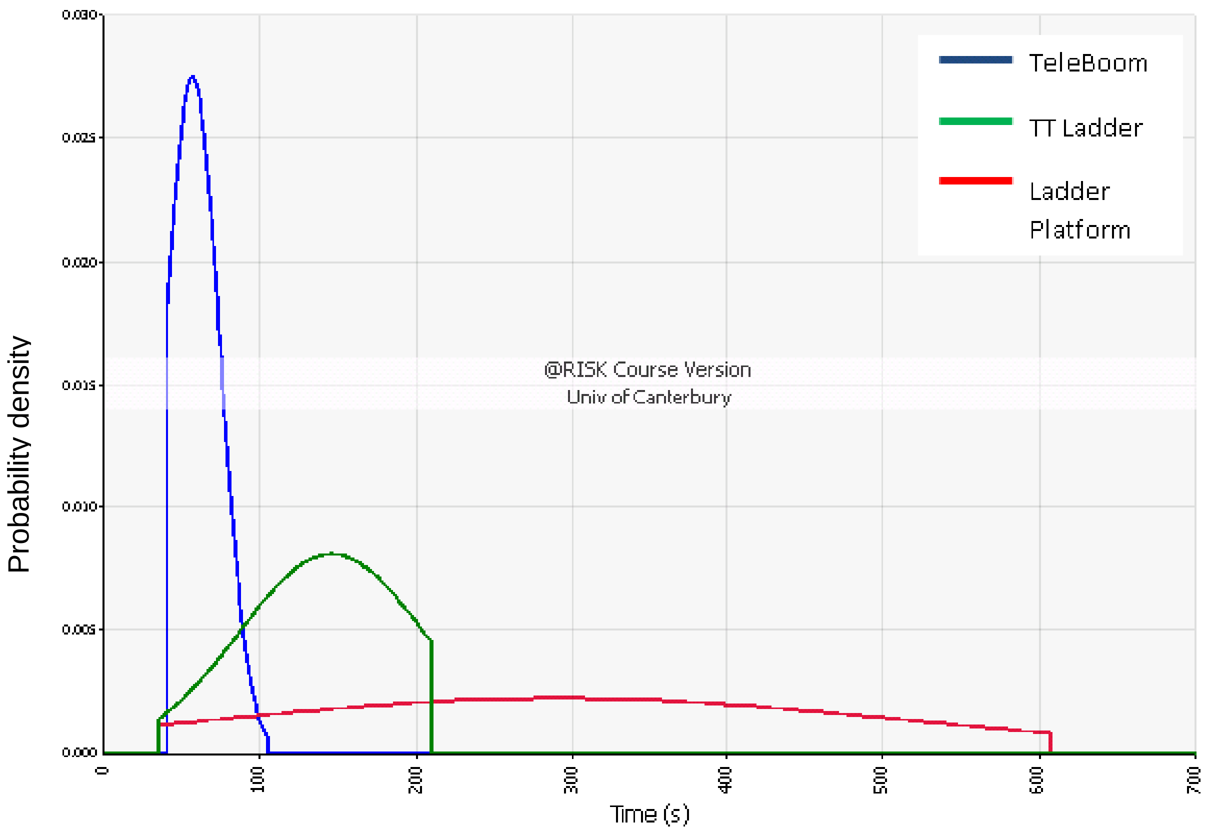


Figure 55 Distributions given within the FBIM for Australian aerial appliances

7.7.1. NZFS Aerial Appliance Data

Due to the significant resources required to undertake specific data-gathering exercises using aerial appliances, only a limited number of exercises have been undertaken to date to collect specific FBIM data. The following section discusses the issues surrounding the data collected so far for each of the aerial appliances investigated.

7.7.1.1. Bronto Skylift F32 RLH

Figure 56 below shows the Type 5 Bronto, a two-manned appliance requiring a Type 3 or 4 pumping appliance to supply it with a pressurised water supply. For a two-man crew to park the appliance and conduct the set-up procedures so that the platform could be raised safely was measured at approximately 284 seconds. The speed at which the Bronto was recorded to raise the platform and train the platform was recorded at 0.2 m/s to its highest elevation and to rotate the platform 360 degrees. It was observed that the elevation and rotation speed did not appear to vary noticeably over its full range. Also, the Bronto is also capable of rotating and elevating simultaneously. However, these speeds account for maximum elevation speeds and do not take into account the times associated with precision location of the basket in close proximity to any particular object such as a building window.

The Bronto is also provided with an extension cord which can be used at the turntable providing for remote control of water monitor operations from the ground level. Such remote control ability is not available with the following less modern appliances.

Figure 56 Bronto Skylift following initial set up procedures ready for crew and equipment to be placed in basket

7.7.1.2. Aerialscope Type 6 23 m Articulated Boom with Platform

The Aerialscope Type 6 appliance is a four-manned appliance with dedicated pump and has been in service for over 25 years. The additional manpower associated with this appliance increases the number of operators available to set it up. However, due to its age and configuration this appliance is significantly more operator-intensive to set up than the Bronto. Whilst it has its own dedicated pump it also has some advantages operationally as it can be supplied with water direct from an external water source. However, this requires further man power to set up dedicated water supplies to this appliance rather than relying on it being supplied from another pumping appliance and taking advantage of that crew to set up the water supply requirements. For a four-man crew to park the appliance and conduct the set-up procedures so that the platform could be raised safely with two crew in the basket took approximately 420 seconds. The speed at which the Aerialscope was recorded to raise the platform and train the platform was recorded at 0.1 m/s to its highest elevation and to rotate the platform. Again, it was observed that the elevation and rotation speed did not appear to vary noticeably over its full range and that it could rotate and elevate simultaneously.

Figure 57 Aerialscope used as a water tower with two crew in the basket operating two independent jets

7.7.1.3. Thibault 30 m Telescopic Turntable Ladder

Three exercises were conducted with the Turntable Ladder: one on level ground extending and rotating the ladder to its maximum elevation as with the other aerial appliances, and two exercises were timed from specific training exercises conducted at real buildings with difficult access issues. The first training exercise was conducted at the rear of a high-rise building on grade and the second exercise was located tightly in-between two high-rise buildings with various services such as drains located in the narrow access way. The purpose of these exercises was to raise the ladder each time to roughly its maximum elevation and reach a specific window of the building from which rescue could be conducted. The exercises highlighted the additional difficulties associated with parking an aerial appliance on a gradient and near various services which needed to be avoided so that the weight of the appliance and stabilisers were not positioned on weak points on the road surface. Whilst this appliance can carry four crew, these exercises were established using only two fire fighters. For two fire fighters to park the appliance and conduct the set-up procedures so that the ladder could be raised safely took 160 seconds on flat open ground, and 340 and 287 seconds, respectively, for the two mock exercises. These times indicate the associated difficulties and times associated with establishing the aerial appliances on uneven and difficult terrain. It was particularly noted that when obstacles such as drains were present, additional times were introduced as these obstacles took operators additional time to identify and place the stabilisers in locations away from these weak points in the road surface. Such problems were not present with the other data collected on stable level ground. The speed at which the ladder was recorded to raise to the specified location also varied significantly at 0.14 and 0.16 m/s for the two mock exercises to a far greater speed of 0.5 m/s to its highest elevation and full rotation of the platform. Again, the elevation and rotation speed did not appear to vary noticeably over its full range and it could rotate and elevate simultaneously. However, when the ladder was required to be located at a specific location and in close proximity to a building, the speed of elevation decreased significantly resulting in an increase in time taken to reach the specific target'. This was observed due to the operator needing increased accuracy with the elevation of the ladder and to ensure that the approach speeds to the building were slow enough so that the ladder would not over-run and hit the building. Figure 58 below shows the ladder being extended with an operator located at the end of the ladder as would occur for a rescue operation.

Figure 58 Thibault 30 m telescopic turntable ladder

Table 41 Proposed New Zealand data additions to FBIM Table Z

Appliance type	Set up(s)			Elevate and manoeuvre appliance 180° (m/s)		
Bronto articulated telescopic ladder/platform	284			0.2		
Aerialscope articulated boom with platform	420			0.1		
Thibault telescopic turntable ladder	160	340	287	0.5	0.14	0.16

Depending on the nature of use, (i.e. use of water tower vs rescue) the aerial appliance will require different levels of accuracy of elevation. Therefore, when using the Thibault telescopic turntable ladder or similar, the faster speeds can be used when a water tower on flat, open terrain is required and the longer and slower times are recommended as upper and lower bounds for more complicated and steeper terrain and when accurate placements of the ladder are required.

The positioning of an aerial appliance is crucial to ensuring that it can be used safely and to ensure that it can be used as intended, i.e. that the appliance can reach the intended target. The positioning of aerial appliances will typically take longer than could be expected for a normal fire appliance as once they are parked and set up has begun it will take a significant amount of time to move the appliance again. The values given in Table 42 have been measured from the various aerial appliances manoeuvring within a site into the final position required before set up. Table 42 also contains the times measured to charge the various aerials at full elevation. As the time taken to charge the monitors will be dependent on the type of aerial, operator skill, pump and water reticulation configuration as well as the degree of extension, it has not been possible so far to break these times down per metre of elevation used. Given that this is such a small fraction of the overall aerial time component and given that a significant proportion of the charging time is dedicated to the operator configuring the pump and filling the pipe work before increasing the pressure, it is considered that there is little benefit in gaining greater accuracy of this particular aspect of the operation. As can be seen from the Australian data in table 40, the times associated with charging the monitors varies significantly, whereas the times found here, albeit with less data, show far less variance than could be expected.

Table 42 Proposed New Zealand data additions to FBIM Table Z

Aerial appliance set–up	Time (s)				Sample size
	μ	σ	Minimum value	Maximum value	
Position aerial appliance (m/s)	1.41	0.27	1.00	1.75	5
Charge monitor (s)	18.6	3.07	14	22	5

The FBIM model provides an additional time component for the preparation times associated with any ancillary safety procedures required to go through when operating aerial appliances. The Health & Safety in Employment (HSE) Regulations applies to fire fighters when working at heights requiring aerial operators to wear harnesses as part of the fall protection requirements. The times associated with donning this equipment and establishing other appliance safety protocols is incorporated into the NZFS values established above and have not been accounted for separately.

Based on the observation from these experiments and from discussing these issues with aerial operators, variations in the times associated with aerial appliance set up have been found to be attributable to the following issues:

- terrain, especially gradient and quality of the surface;
- times associated with determining the most suitable location;
- operator experience;
- purpose of use, i.e. use of water tower vs rescue will require different levels of accuracy of elevation;
- type and particular make of the aerial appliance.

7.7.2. Rescue Using Aerial Appliances

It is difficult to establish the times taken to rescue trapped persons from buildings using aerial appliances as there are so many variables outside of the control of the fire services. An exercise has been undertaken to try and quantify the time associated with rescuing victims from a building and the perceived difficulties using an aerial appliance. This exercise was conducted with eight volunteers using the Thibault TTL appliance from a six-storey fire service training tower under ideal conditions. The escape height of the tower measured from the ground level to the sixth floor level was 19 m. The time taken for the volunteers to descend the ladder was approximately 7.5 minutes, taking on average 1 minute per person. It was specifically noted that the last remaining volunteer had reservations about descending the ladder and required additional assistance from a fire fighter to guide that particular individual down the ladder. This hesitation increased the time taken for this occupant to descent the ladder and identified the additional time delays that could occur for occupants with vertigo and who may be hesitant to descend a ladder from such a height. Recognising that the exercise was undertaken under ideal conditions and with volunteers, the calculated time may not accurately reflect ladder descent times under emergency conditions but does provide an insight into the difficulties associated with ladder rescue and provides an indicative time value should such a rescue method require inclusion into any assessment.

Figure 59 shows the second from last person being guided down by a fire fighter while the other people were confident in descending the ladder on their own without any support.

Figure 59 Firefighter guiding occupant down the TTL aerial appliance.

7.8. Effective Length of Fire-fighting Hose for Design Purposes

Calculation of hose run distances inside and outside of buildings will be required for FBIM purposes and if undertaking designs in accordance with the Acceptable Solution (6) for establishing internal fire hydrant requirements, for example. For planning and design purposes, designers typically measure hose run distances off plans assuming a straight line with no loss in hose length due to kinks, obstacles or other issues. For FBIM purposes, the effectiveness or efficiency of hose-laying operations should be recognised as set up times are established on the number of lengths of hose used given the distance between targets such as an appliance and hydrant, requiring the number of lengths of hose that would likely be used at an incident to be determined. This section provides data collected from real incidents to establish an upper limit of hose-laying effectiveness so that the number of sections of hose likely to be used during an incident can be estimated.

The FBIM provides times associated with hose operations per section of hose used. As only full lengths will ever be used, the distances over which hose will be run and thus number of hoses used to cover any distance needs to incorporate movement around obstacles and inefficiencies associated with laying out the last 45 mm branch man's length and the natural lie of the hose once pressurised.

To understand the optimum efficiency of hose-laying operations for planning purposes, measurements were taken during two large fire incidents to ascertain the effective length of hose-laying operations in service. The sixth and fifth Alarm fires at the Southdown freezing works complex in Auckland in 2008 and 2010 were protracted incidents requiring significant water resources. During the 8-day and 2-day incidents, water was relayed to the site in some cases from distances exceeding 1 km using 90 mm lay flat delivery hose and with pumping appliances providing water relays to maintain water supply pressures over these distances as shown in Figure 60 and Figure 62.

Figure 60 Feeder hose supplying water from a remote source

Figure 61 Fire pumping appliance used as a relay to maintain pressure in feeder hose over long distances

During attendance at these two incidents, seven different hose sets of hose runs were measured and logged including those hoses laid over long and medium distances. Four of the data sets were taken from hoses laid using a specialist hose-laying vehicle and fire-fighters over a flat and relatively straight asphalt road. Also, a number of relatively short feeder deliveries were measured from the standpipe to pumping appliances within the site. The number of hose lengths used and the distance between the standpipes used to access water from the in-ground hydrants and the final pumping appliance inlets were measured as would be done from site plans used for design purposes, in a straight line from point A to point B including any obstacles. The results from the seven data sets are provided below in Table 43 and provide a very good agreement from all the data sets for an effective hose length per section of hose to be 87%. Given that the majority of the hose was laid on flat straight ground with few obstacles affecting the hose laying indicates that even in relatively ideal circumstances the full length of hose is unlikely to be utilised.

Table 43 Effective lengths of feeder hose used during fire incidents

Data set	Number of hose (30 m lengths)	Length of hose (m)	Distance covered (m)	Efficiency %
1	36	1080	953	88
2	43	1290	1132	88
3	29	870	730	84
4	28	840	730	87
5	12	360	310	86
6	7	210	181	86
7	9*	265*	223	84
Total	164	4915	4259	87 (μ= 86)

*1 length of 70 mm diameter 25 m length of hose used

The hose run lengths considered above were for long and medium length distances and are considered to be at the upper limit of hose laying effectiveness. For shorter distances where fewer lengths of hose would be used, the effectiveness can drop significantly. Figure 62 below shows the problems that can occur with laying hose in cramped and restricted spaces over short distances. Where the distances between water supplies, fire appliances and fires are short, full length of hose will still have to be run out and once placed in specific locations and charged with water they cannot easily be moved. This potentially results in redundant hose lengths being left and new ones being run out, should operational tactics change during the course of the incident.

Figure 62 Congested hose laying occurring within restricted space

For the purposes of the FBIM and operational planning, only an upper limit of fire hose laying capability is required for assessment purposes where times to lay hose are given per length of hose. The information presented above suggests that an upper limit of 87% be used for laying hose lengths giving a maximum effective reach of a 90 mm, 30 m length and a 75 mm, 25 m length hose of 26 m and 22 m, respectively.

For example, where a direct distance of 70 m was measured between an appliance access position and the building fire hydrant inlets or any point of interest, four lengths of 75 mm, 25 m length hose would be required to reach the inlets from the appliance, not three as could be expected if a hose length of 25 m was assumed.

7.9. Other Methods of Data Collection

Other methods of data collection including using fire fighters to record fire ground activity times and using fire appliance-mounted cameras internally and externally were considered but dismissed for varying reasons. Also, fire incidents recorded on amateur and professional videos were viewed to try and capture times of the activities shown. At the time of conducting this research, a television documentary following the NZFS at emergency incidents was being made. Footage for the documentary has been commissioned from a number of independent sources to provide live fire incident footage. A significant amount of this footage was viewed in an attempt to source real fire ground activity data. Also, the internet provides a significant resource of video footage from real incidents. However, from the videos studied to date, little in the way of good data could be sourced as footage typically did not show complete activity times, making this method of data collection unsuccessful. Due to the resources required to undertake this method of data collection and the trivial amount of data that was able to be gained from this footage, this method of data collection was eventually abandoned.

CHAPTER 8. Verification and Validation of the FBIM to New Zealand Conditions

8.1. Introduction

This chapter aims to provide validation of the data collected within this project and to provide verification by identification of any inherent differences between the methodologies presented in the FBIM and current NZFS procedures. A number of different methods have been used to compare the results obtained within this research with the times and procedures found at real incidents. The methods presented within this chapter include:

- comparison of the statistical data sets with actual attendance at specific buildings of interest;
- attendance at numerous large-scale and protracted fire emergencies;
- observations made from being present and on shift at fire stations;
- undertaking fire ground field experiments.

8.2. Validation of Proposed FBIM Response Time Data

To validate that the proposed distributions given in Chapter 7 provide realistic response times compared with those found at real incidents, the proposed distributions were included in a partial FBIM analysis using a probabilistic Monte Carlo analysis following the FBIM method set out within the manual (5) and compared with the actual response times to incidents at a specific building. For this particular example, a building was sourced that had been responded to on multiple occasions to provide a representative comparison. The chosen building had received 72 appliance responses from emergency incident calls over an eight-year period ranging from 111 emergency calls to notification from the installed automatic and directly linked detection systems within the building. As the nature of every incident was not under scrutiny, this analysis only included the response times recorded within the NZFS incident database, from the time NZFS was notified of an incident to the time of arrival of the first appliance.

A number of assumptions were made such as the closest located fire appliance would arrive first, and that it was located at its home fire station at the time of receipt of the call. The travel distance from the fire station to the building street address was taken from

Google™Maps (70) as 1.8 km. The following distributions were used along with the methods set down in charts 2, 3 and 4 from the FBIM manual:

Chart 2, times for dispatch; lognormal μ = 26.8, σ = 14.6, shift −0.85;

Chart 3, time to assimilate; loglogistic Γ = −308.3, β = 384.7, α = 25.5;

Chart 4, design speed; normal μ = 41.8, σ = 22.2 min = 12, max = 100.

The software package @Risk was used to find the calculated response time using Monte Carlo analysis and Latin Hypercube sampling. A total of 100,000 iterations were run, sufficient to ensure convergence. Figure 63 shows the comparison of the FBIM calculated distribution and the fitted distribution found from the 72 response times to the subject building.

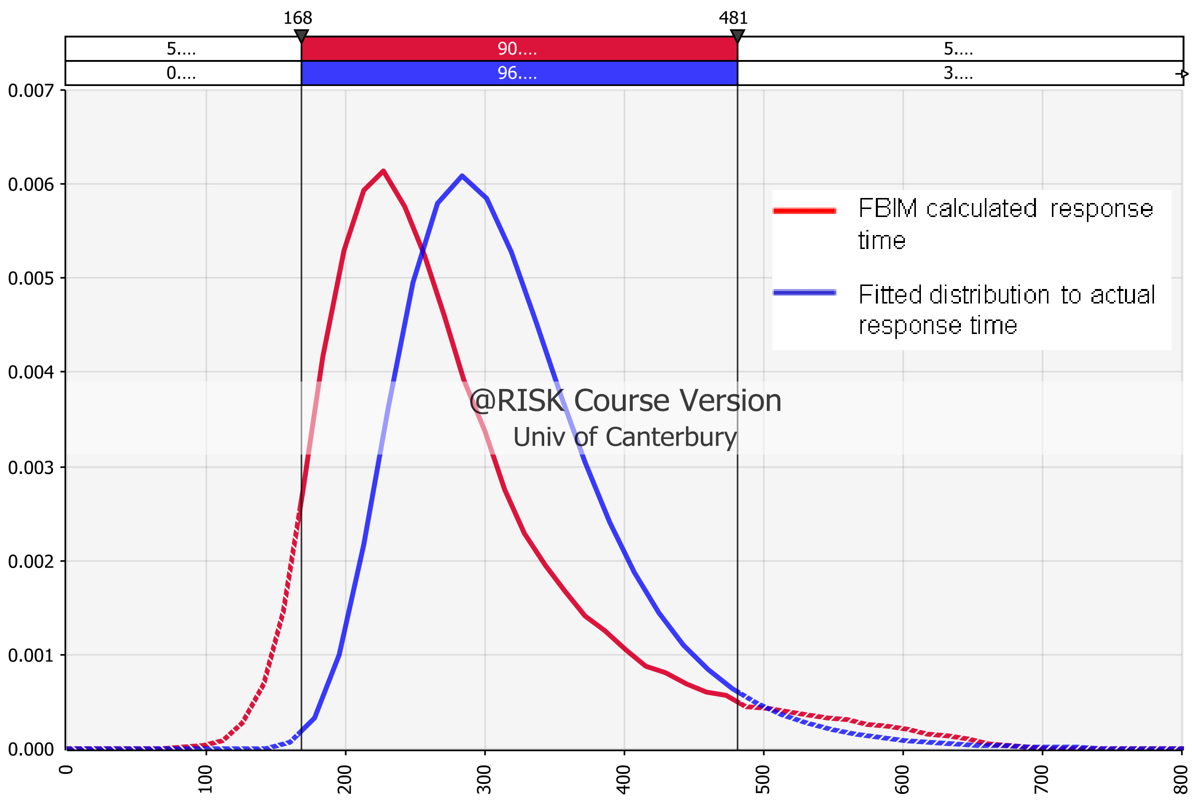


Figure 63 FBIM and real incident response time verification (seconds)

Table 44 compares the calculated response times and associated values for the fitted distributions that describe both the actual and calculated response times to the subject building. As can be seen from both the graph and values presented in the table, the calculated times compare well. When comparing the maximum expected response time to this subject building, the calculated times only deviate by 18 seconds 95% of the time. This compares to only 27 seconds when comparing the 95% result from the actual data set.

Given the available sample size, the responses found compared with actual incident data indicate that the FBIM method and the fitted distributions presented can predict the expected response times to buildings accurately. The difference between the lower response times found using the FBIM methodology indicate the times that could be expected on the very rare occasions that small values for fire-fighter response times, for example, could occur.

Table 44 FBIM and real incident response time verification (seconds)

Response time (s)	Minimum value	Maximum value	5th %	95th %	μ	σ	Sample size/iterations
FBIM analysis	61	783.8	168	481	278	96	100,000
Fitted distribution	134	1016	217	463	318	77	100,000

The results from the actual incident data include data from the first arriving appliance which was not always from the closest located station as assumed when using the FBIM methodology. Where sufficient resources are available, such as in the main cities as was the case for this specific building, the results from this analysis indicate that it is not necessary to discount a response from the closest located fire station as the travel speed distribution takes into account the associated slower response times of appliances under certain travel conditions. In these circumstances, when the slowest appliance speeds occur, appliances from further away from the building travelled faster and arrived prior to the appliance from the closest station.

Figure 64 shows a regression sensitivity analysis for the calculated response times to the subject building. As to be expected, the result was most sensitive to the distance travelled (albeit a relatively short distance in this example of 1.8 km).

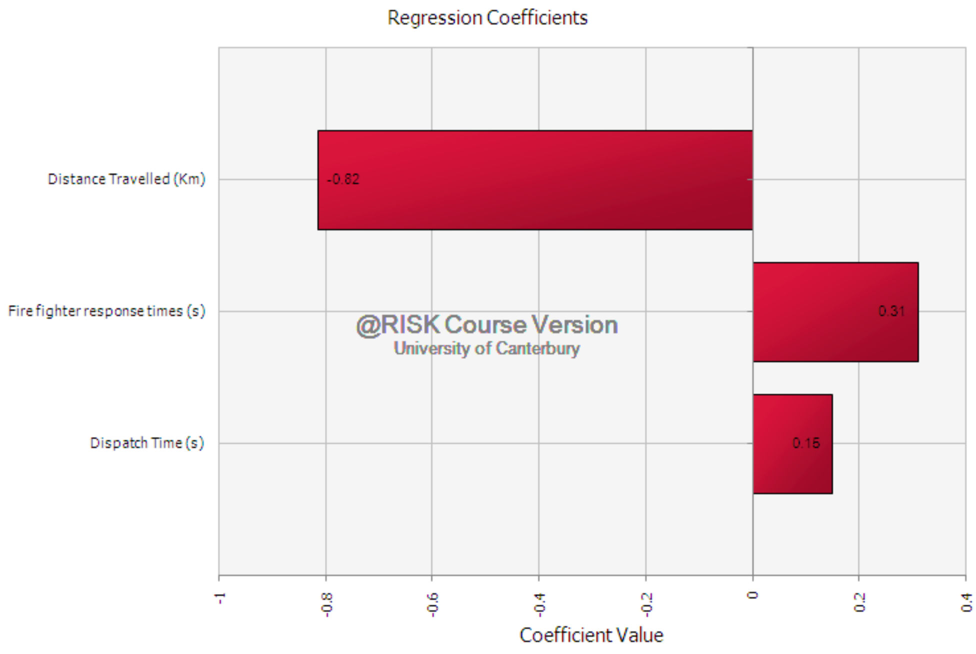


Figure 64 Sensitivity analysis for calculated response time

As the travel distance accounts for the largest response time factor, where there are significant distances from the subject building to the second and third closest located fire stations, it would not always be appropriate to assume that the closest station would arrive first.

8.3. Attendance during Large Emergency Incidents

To provide a level of verification and validation of data collected within this project and to identify any inherent differences between the methodologies present within the FBIM and current NZFS procedures, attendance at real incidents was recognised to be fundamental to this research. Numerous large scale and protracted fire emergencies were attended throughout the period of this research in an attempt to collect data and indentify any procedural differences to that assumed within the FBIM. Notification and attendance at these incidents was undertaken via pager notification under non-emergency response conditions. Attendance at numerous incidents during this research identified the significant difficulties with trying to collect and establish real incident data. The immediate problem associated with attendance at real incidents and data collection is that the tasks of immediate interest typically involve the first arriving appliances and tasks undertaken by the first arriving fire fighters. Relying on notification by pager and arriving even under the most efficient conditions would typically mean that attendance at any of these incidents would occur well after the first appliances had arrived and many of the tasks undertaken by fire fighters under emergency conditions had been completed. Attendance also indentified the significant challenge and difficulties of trying to collect data given that access to the scene can be difficult, access into the buildings of interest is typically impossible until after the incident has finished. Viewing and recording incidents from outside the building and without being able to follow fire fighters closely removes the ability to collect specific fire-fighter data. Also, the collection of data associated with equipment and appliance operations is not possible as most tasks and those required under emergency conditions were typically completed by the time of arrival.

Whilst attendance at these incidents proved to be of little benefit with respect to the collection of FBIM data, it has been found to be beneficial in providing experience and gaining knowledge of NZFS operations and procedures during large-scale fires. Observing fires and NZFS operational procedures first hand has been found to be of great benefit when comparing the FBIM and the tactics adopted by the NZFS.

For the purpose of collecting and providing a level of validation to the FBIM, it has been concluded from these incidents that attendance at fires needs to occur during the earliest stages of an incident and with the first arriving appliance.

8.4. Real-Time Incident Attendance and Observation

8.4.1. Introduction

Experience from attendance at real fire and emergency incidents suggested that the perspective gained by observing incidents first hand would need to include observations from arriving at the scene at the earliest possible stage. Time was spent at a range of fire stations with the intention of attending emergencies and gaining data first hand. Observations were undertaken during a night shift at six different fire stations in Auckland and Wellington consisting of 10 shifts totalling 120 hours of effort. During these shifts, 14 emergency incidents were attended, providing data samples for verification of the FBIM data. Of these incidents attended, only three were fires and data other than response times to the incident location was not able to be recorded. As a result, validation of the times taken to undertake fire ground activities including fire-fighting operations was not able to be achieved.

8.4.2. Appliance Response Speeds

Attendance and observations at fire stations has allowed the recording of the times taken for fire fighters to respond to emergency calls and to ascertain the actual average speed travelled by a fire appliance to an emergency incident. A number of different data collection methods were considered and trialled. The use of a digital Dictaphone recording the incidents was found to be most successful as this allowed for the recording to be started as soon as the fire station was notified that attendance at an incident was required until the appliance returned back to the station. This allowed the times taken from the recordings to be compared with those times taken from the ICAD records. For the purposes of gaining an understanding of the travel speeds, the routes could be plotted on a mapping system and compared with the times actually taken under 'lights and sirens' to travel that distance. The information specific to each incident attended including a description of the road and traffic conditions is provided in Appendix E. The average travel speeds found are shown in Figure 65 and indicate the average speeds travelled as a function of the distance travelled. Two distances are provided for comparison, the actual distance travelled along the route taken and the distance from the appliance starting location (the fire station) in a direct and straight line to the incident location.

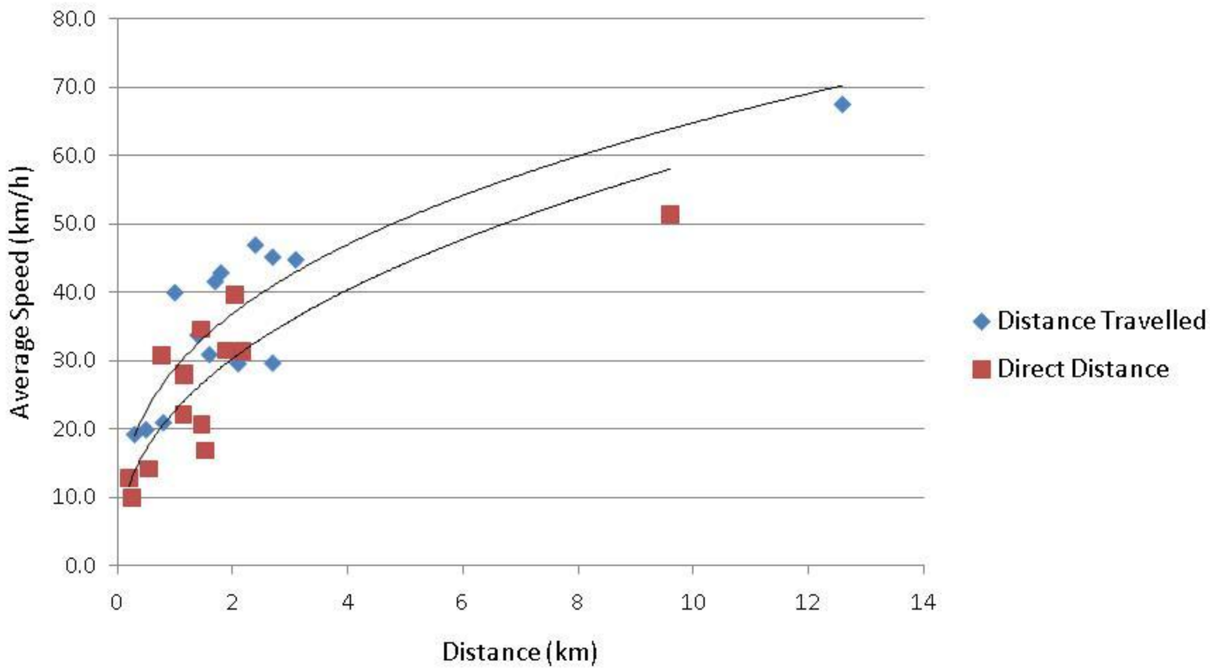


Figure 65 Average speeds found when travelling to actual emergency incidents

As can be seen, the actual average travel speeds found varied significantly. There was also no linear correlation found between the average speed and distances travelled. Of the 14 incidents, 13 occurred within relatively short distances, less than 3.1 km from the stations visited, which is to be expected given that these were fire stations and responses within the Auckland and Wellington CBDs. One motor vehicle incident occurred 12.6 km from the station, which required the specialist rescue equipment on this particular appliance. The data was scrutinised to test any correlations between the two CBDs and by isolating the attendance at the motor vehicle incident . The closest relationship found was that using a power relationship with the r^2 correlation of 0.84 when using the following curve:

$$Y = 125x^{0.635} \quad [2]$$

where y is the time in seconds and x is the distance travelled in km. These findings and this relationship conflicts with the previous studies discussed here that found that for short distances, travel time increased with the square root of the distance and that for long travel distances, the travel time increased linearly (63). However, given the relatively small data set and that no such correlation was found with the larger data set discussed in Section 7.5.3, this correlation is not recommend for practical use.

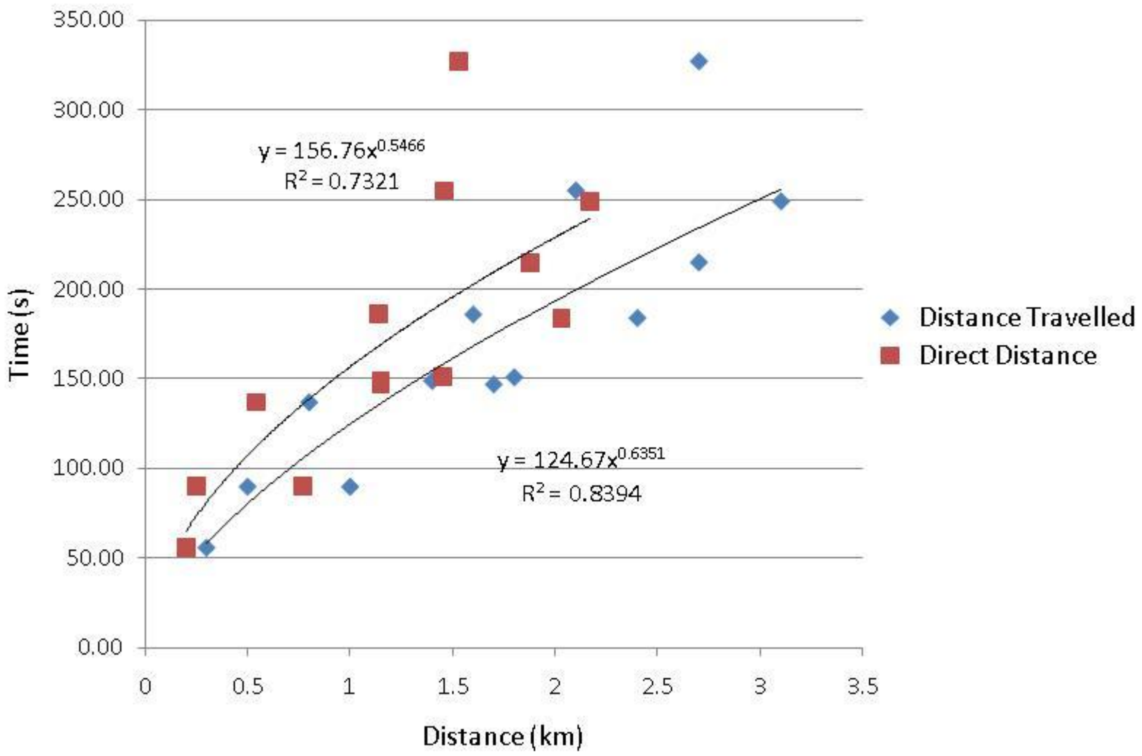


Figure 66 Power trend line relationships for the average speeds found when travelling to actual emergency incidents

8.4.2.1. Distance Verification

To validate the distance measurements provided using the TransCAD Facility Location software tool (68), the distances travelled to the incidents were verified using Google™Maps (70) and compared. Table 45 shows the difference between the two methods of establishing fire appliance travel distances to each incident attended, rounded up to the nearest 0.1 of a kilometre. As can be seen from Table 45, where differences existed between nine of the 14 data sets, six of these were within 0.1 of a kilometre with only a single data set being 0.3 of a kilometre different to that predicted by either method.

Table 45 Distances to incidents taken from TransCAD and Google™Maps

Incident number	TransCAD distances	Google travel distance	Difference %
1	12.6	12.6	0
2	2.4	2.4	0
3	2.7	2.7	0
4	1.5	1.6	6.2
5	0.4	0.5	20
6	0.3	0.3	0
7	1.7	1.8	5.6
8	3.0	3.1	3.2
9	1.5	1.7	11.8
10	0.9	1	10
11	2.4	2.7	11.1
12	1.5	1.7	11.8
13	2.1	2.1	0
14	1.3	1.4	7.1

Figure 67 shows the strong relationship and accuracy of the TransCAD distance predictions compared with the actual routes and distances found during attendance at these incidents using Google™Maps.

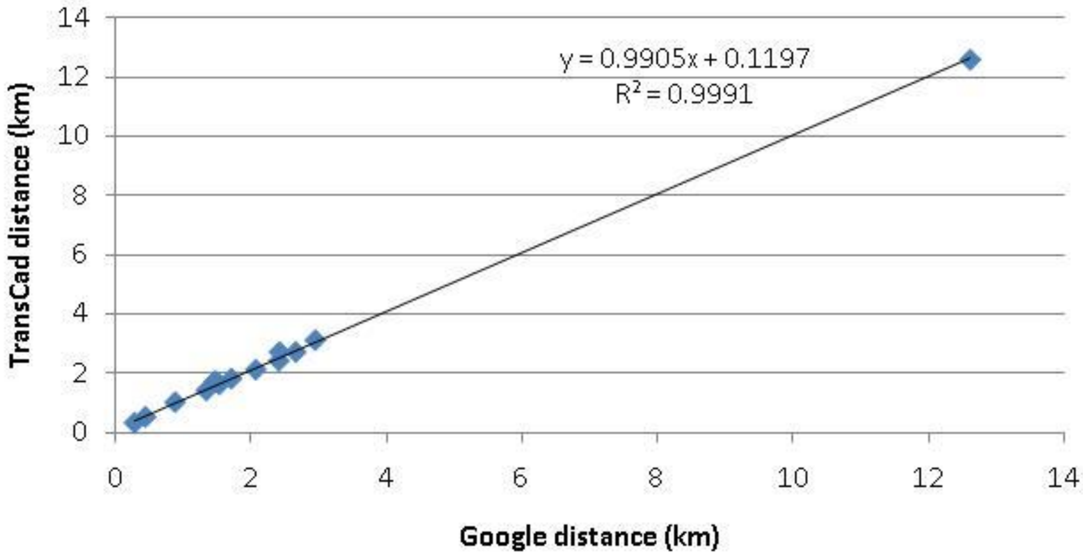


Figure 67 Distances from TransCAD and Google™Maps compared including linear trend line

8.4.3. Conclusion

Attendance at incidents and observing the tasks directly has provided the following verification and validation of the FBIM.

Verification:

- that the procedures used by the attending crews is that assumed within the FBIM;
- that the times recorded by the (ICAD) system and reported within the Fire Incident Reporting System (FIRS) are consistent with the observations at incidents.

Validation:

- that the times recorded by ICAD/FIRS are accurate;
- that response times at real incidents are commensurate with those found within the statistical collection, including:
  - times for alarms/fire verification and any notification delays;
  - times for fire-fighter response;
  - speed data for appliance travel.

8.5. Fire Ground Field Experiments

A number of full-scale exercises were conducted to attempt data collection that could be validated against an FBIM analysis for the buildings used under different scenarios. Two full-scale exercises (Exercise A and B) were undertaken during the period of this research to provide a degree of validation against the FBIM and the current computer model. Both exercises made use of a large industrial facility which included a two-storey office block attached to a warehouse and production factory. Figure 68 shows the basic layout of the site taken from the NZFS operational plan for the facility. As the facility was scheduled for demolition, it provided a unique opportunity to undertake a large scale event and training exercise within a recently operating facility which could also be used to collect data to validate the FBIM.

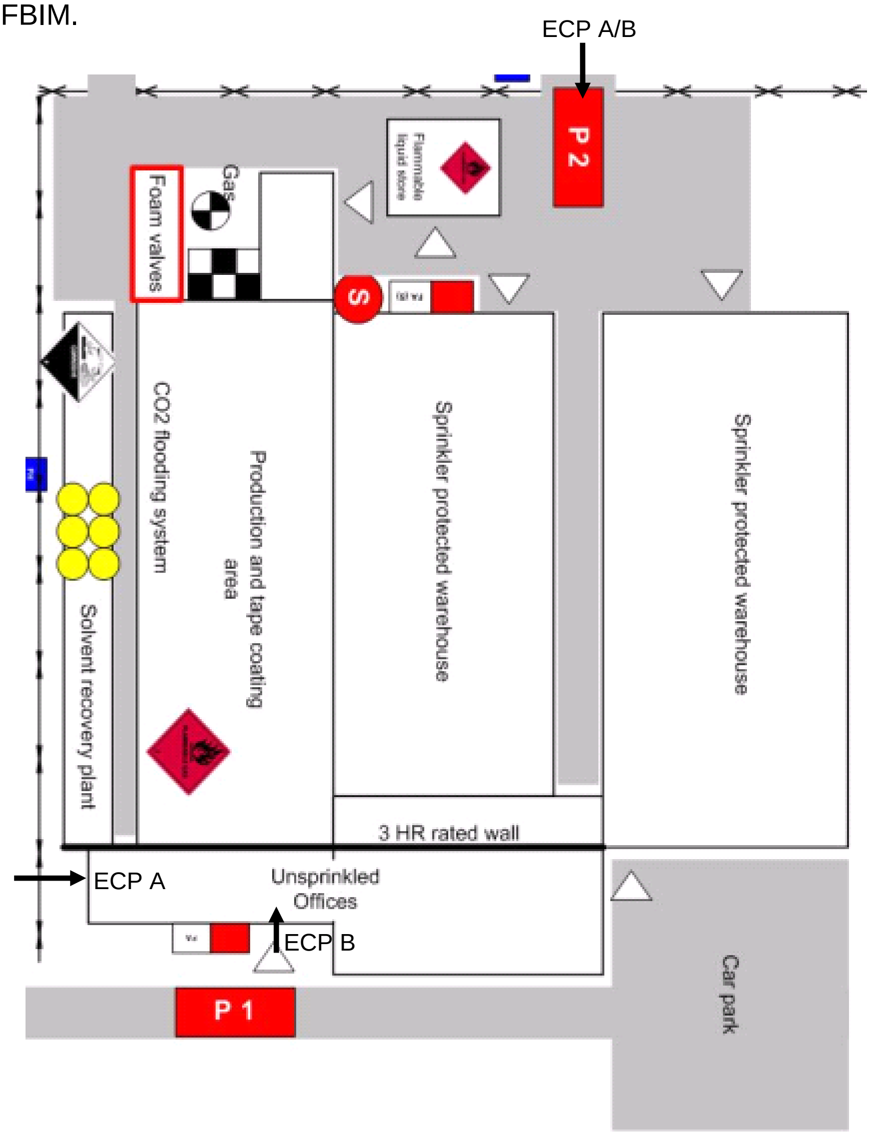


Figure 68 NZFS operational plan of facility used for validation exercises

Exercises A and B were undertaken on different days utilising different crews including volunteers for Exercise A and career fire fighters for Exercise B. The objective for both exercises was to simulate an uncontrolled fire occurring within the second floor offices with two occupants located at the upper level requiring rescue. For both exercises, the crews were provided with a safety brief and were informed about the basic nature of the event and asked to undertake the exercises simulating emergency conditions, in line with NZFS Standard Operational Procedures (SOP). None of the crews had specific previous experience undertaking operational exercises at the site, although there was some level of familiarity with the site and facility with some of the crews that were local to the area. To replicate realistic arrival conditions, the responding appliance and crews were initially located remote from the site and were notified of an incident through the NZFS dispatch system. This prompted the first two dispatched appliances to travel a short distance on public roads at normal speed to the location of the site. On arrival at the building the crews travelled to the main front entrance and rear of the building in accordance with SOPs and were met at the front of the building by a safety officer who gave the first arriving officer specific details of the incident. This information included a statement that two persons were unaccounted for and believed to be located on the upper office level. The safety officer also prompted the first arriving crew in Exercise A to make entry through a side door, not the main entrance, which provided a slight variation between the two exercises.

Due to the size of the site and predetermined tactical plan, appliances were sent to both entrances, termed here as entry control points, at the front and rear of the building to establish operations. On arrival and on notification of missing persons reported, the first arriving crews, in line with standard operational procedures, were prompted to call for additional resources using the correct communication protocols. Further appliances were then turned out remote from the site at various intervals to simulate them arriving from various locations, as would occur in practice. At Exercise A, six appliances were utilised consisting of four Type 3 appliances with full crews and fire police units for traffic management. Exercise B utilised five Type 3 appliances, a Type 6 aerial appliance, breathing apparatus appliances, command unit with full crews and other support staff.

8.5.1. Recording of Information

During the two exercises, specific methods of recording the times associated with each specific task were used using numerous personnel. Due to the size of the complex, size of operations, complexity of the exercises and number of tasks being undertaken concurrently by the various crews, collecting the data became a difficult task and became limited by the resources made available to collect the data.

Various methods were used to collect the data including the use of a video camera, stills photography, a Dictaphone and stopwatches. In total, five people took part in data collection in the first exercise and three in the second. Initially, data was intended to be recorded by following the crews from both the front main entrance and rear of the building to identify the differences in the tasks expected to occur between the different entrance configurations. At the front of the building was an office and at the rear a processing facility; different way finding and travel characteristics were to be expected from the crews. Located at the rear of the building were the sprinkler pump, valve house and inlet connections as well as repeater FAP. Crews arriving at the rear of the building were required to establish water and prepare to boost the sprinkler system should it be required, then make entry to the building to begin simulation of search or suppression activities.

For safety reasons and to ensure that the data collection and observers did not interfere with the operational activities, it became difficult to establish the times taken for all the activities that occurred and for individuals to record all of the activities that occurred with crews moving inside, outside and around the building. During both exercises, smoke machines using theatrical smoke were used to simulate fire conditions within the upper floor. Whilst this was considered necessary to require the fire fighters to undertake search and rescue operations in accordance with SOPs and to simulate difficult operating conditions, the use of the smoke machines made the recording of fire-fighter activities on the upper floor extremely difficult.

For the purposes of collecting and collating data from this type of exercise, the most reliable method of collecting and analysing the information was found to be from the video recordings. Collating the data collected from the other methods became particularly difficult depending on the quality of the information recorded and the level of information recorded by each individual, especially when trying to identify what task was undertaken, by whom, and to establish the timeline of events. The use of video recordings proved invaluable in establishing the timeline of events and what tasks were actually undertaken and in what sequence, given that the majority of the exercise could not be witnessed first hand.

8.5.2. Results

Figure 69 shows the main building outline with the approximate parking locations of fire appliances, feeder and delivery hose locations as laid and the entry control points shown for both Exercises A and B. As dictated by the pre-operational plan for the building and standard tactics in both exercises, the first arriving appliances from which the hoses were run into the building were parked in approximately the same locations as indicated. Appendix H contains the raw results of both exercises in tabulated and Gant chart form, showing the sequence of task completion as they occurred and as could be established from the various data collection methods used.

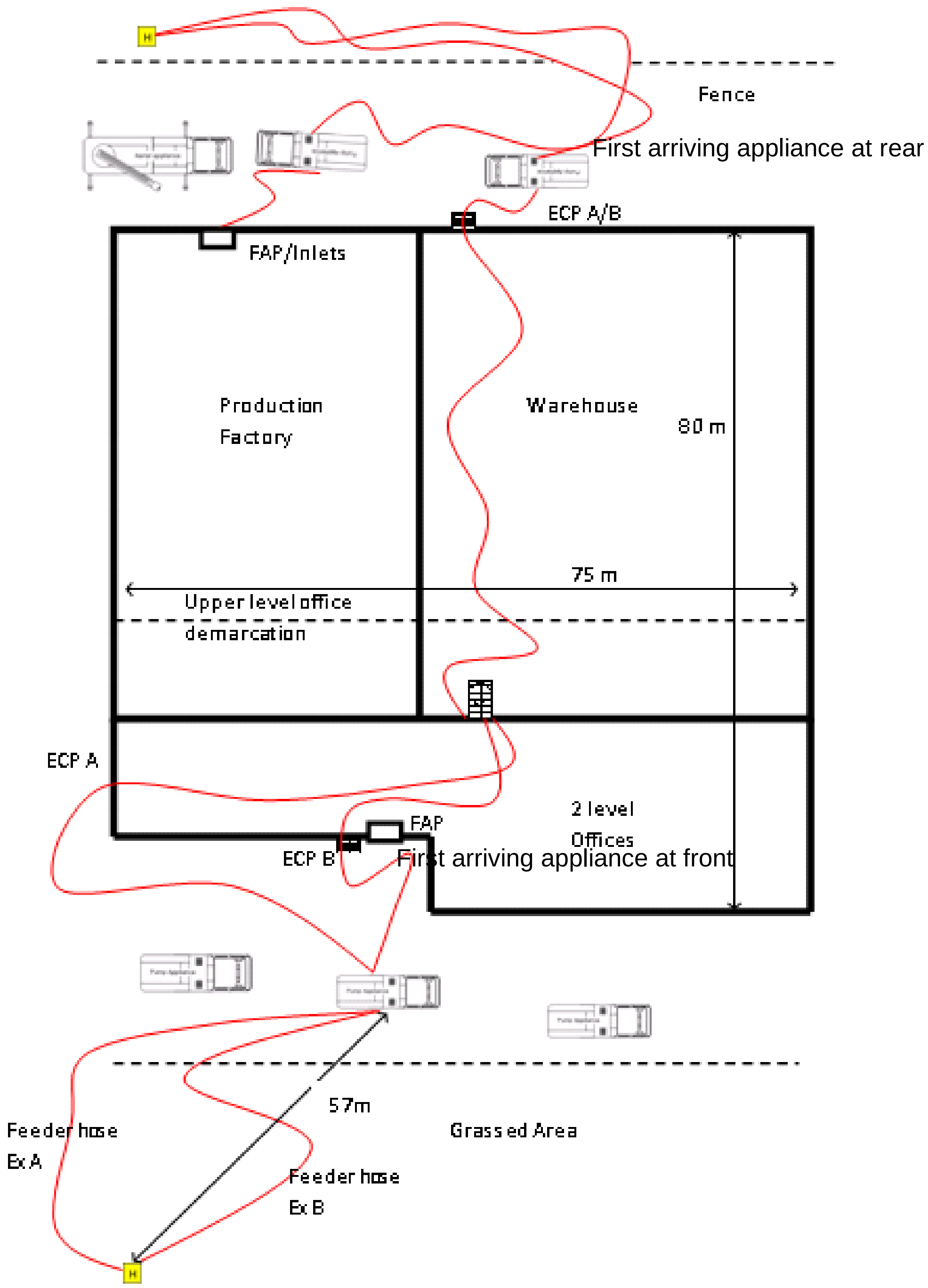


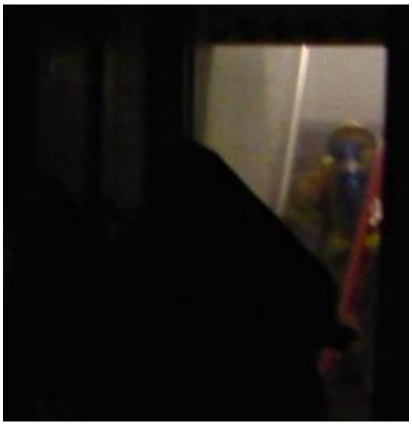
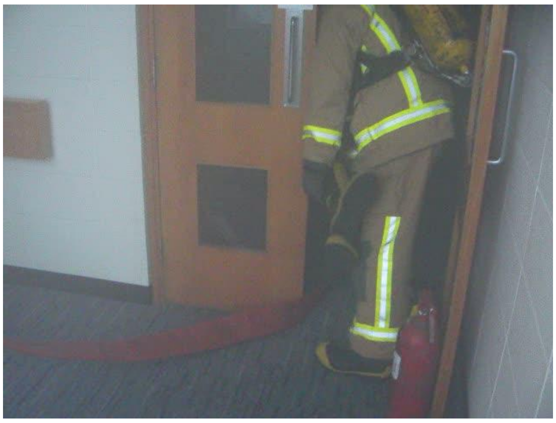
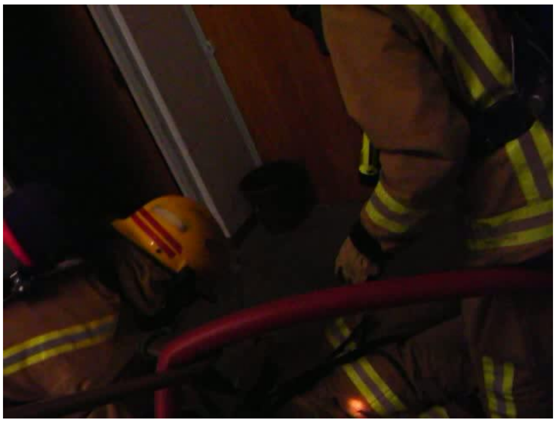
Figure 69 Building layout shown with feeder and delivery hose runs and entry control points (ECP) as used in Exercises A and B

For the purposes of validation against the FBIM computer program and its methodology, an analysis was undertaken using the FBIM computer program and the existing Australian data, the parameters of the building, and based upon the time taken for the first two fire fighters to reach the head of the stairs, to make entry into the offices at the second level. The analysis has not been carried through to completion due to the difficulties associated with establishing task times on the upper floor offices due to it being smoked logged in both exercises. Because the method, direction and travel distances the fire fighters used to undertake the search and rescue activities could not be established, validation from this point onwards was not possible.

There were two major differences between exercises A and B in the way in which the exercises were conducted. To mitigate the potential for water damage to the building, charged hoses were not used for Exercise A. This would have resulted in operational efficiencies due to reduced hose weight of and increased manoeuvrability compared with the use of charged hoses. In Exercise B, the hoses were charged with water but not to full operating pressure. The increased difficulty associated with manoeuvring charged hoses due to their increased weight and stiffness was obvious from the exercises, but was not able to be specially assessed within this analysis. However, in Exercise A fire fighters were directed to use the side entrance rather than the main front entrance where the FAP was located. This difference added an additional 30 m from the appliance to the entrance and an additional 30 m of extra internal travel compared with that experienced by the crews in Exercise B. Therefore, if a direct comparison of the exercise times is made, the advantage that the fire fighters in exercise A had by using empty hoses was minimised by the additional travel distance they had to cover compared with the fire fighters in Exercise B. Table 46 shows a photo log of the key tasks undertaken with approximate times for comparison.

Table 46 Photo log of Exercises A and B taken from video footage showing key tasks with approximate times for comparison

Exercise A	Exercise B
1A. Arrival 0 seconds 	1B. Arrival 0 seconds 
2A. Don BA 290 seconds 	2B. Don BA 270 seconds 

3A. Enter compartment at head of stairs 821 seconds 	3B. Enter compartment at head of stairs 825 seconds 
4A. Victim recovered at head of stairs 1259 seconds 	4B. Victim recovered at head of stairs 1720 seconds 
5A. Victim reaches building exit/entry point 1359 seconds 	5B. Victim reaches building exit/entry point 1804 seconds 

An FBIM analysis was undertaken using the FBIM computer software based on the building and site layout dimensions as would be expected to be undertaken within a performance-based design. Table 47 shows a summary of the main input data and assumptions used within the analysis. The analysis followed the tasks expected to be undertaken by the first arriving crew and the times taken to establish water supplies to the appliance and lay, connect and charge internal delivery lines so that a delivery would be established at the head of the stairs, so that entry could be made into the compartment containing the fire.

Table 47 Summary of input data and assumptions used within FBIM analysis

FBIM chart	Activity/task		Value
1-4	Not used		
5	Premises occupied		Yes
	Fire warden present		Yes
	FAP to be interrogated		Yes
	Building area		$2000m^2$
6	Flush hydrant		Yes
	Remove -	Hydrant equipment	Yes
		High rise pack	Yes
7	Additional resources required		Yes
	Distances for Officer in Charge (OIC) to walk to set up area		50 m
9	Side hung doors to be negotiated		3
10	Travel with 65 mm -	Horizontal travel	20 m
	hose	Vertical travel	20 steps
11	Water supply set up -	Hydrant to appliance	57 m
		Hose appliance to branch	90 m
		Charge delivery hose	90 m
12-16	Not used		

Table 48 shows a summary of the results of the two exercises for times taken to establish water at the head of the stairs of the office compared with results for the same parameters using the FBIM computer program and Australian data with a 95th percentile confidence limits. The full FBIM Computer Program results for Exercise B are given in Appendix I.

Table 48 Comparison of Exercise A and B results with those of the FBIM analysis

	Time taken for fire fighters to establish water at head of stair (secs)	Comparison with 95th confidence level of FBIM prediction (secs)
Exercise A	821	−72 (−8%)
Exercise B	825	−68 (−7.6%)
FBIM prediction	893	N/A

Table 49 provides a summary of the individual component values that were able to be isolated for direct comparison against the existing FBIM data. The table presents the value taken from the exercise and converted into the unit provided in the FBIM data tables for ease of reference. Due to the difficulties experienced in recording the data during the exercises and because a number of individual tasks were not completed as single tasks during the exercise (i.e. some tasks were not fully completed before others were started), only 21 individual component times were able to be isolated from the data collected. As can be seen, all but thee of the results fell within the given FBIM distributions. The travel speeds associated with *'Q - Firefighter horizontal travel speed'* can be explained considering that these values included the times taken to search for the fire hydrants and also to familiarise themselves with the building. As explained previously, the unfamiliarity with the site required the fire fighters to search for the fire hydrant and to familiarise themselves with the building layout. Additional times are incorporated within the FBIM to account for these additional delays which have not been removed from the component times presented here.

A significant difference in the individual times taken for the fire fighters to *'dismount appliance and don BA'* occurred between the exercises. This was due to the BA being locker-mounted in Exercise A and seat-mounted in Exercise B. The times associated with the locker-mounted BA exceeded the FBIM distributions significantly, indicating an anomaly between the data sets. This can be explained as the fire fighters in Exercise A prepared and donned their BA sets in a manner appropriate for a long protracted incident; they set up a BA station, including placing a tarpaulin on the ground and placing their BA sets on that rather than wearing them directly from the appliance as would be expected for immediate entry to a building.

The remaining component times generally fall below the mean times reported within the FBIM indicating that the remaining components of the exercises would have taken longer and would have been at the tail end of the distributions given that the overall times were found to be at the 72nd and 98th percentile values when compared with the FBIM computer program results.

Table 49 Individual component results from Exercise A and B compared with those from the FBIM data

FBIM activity data table reference	Existing FBIM data		Exercise A and B data	
	Mean (μ)	95%	Value	Percentile
Q1 – dressed in turnout uniform	2.3	4.6	2	41.5
			2.85	65.3
Q2 – dressed in turnout uniform with equipment	1.9	4	1.2	29.5
Q3 – dressed in turnout uniform in BA with or without equipment	1.4	2.2	0.18	<1
			0.75	10
			0.57	5
			0.67	7
P1 – hydrant equipment	32.5	62.3	24	32
O1 – flush hydrant	32.8	66.7	32	49
			30	45
V1.1 – remove, connect & charge hose from hydrant to appliance	144.7		87	26
			86	26
V4.1 – charge delivery hose from appliance	20.3		10.3	23
T1 – ascend stairs in BA with equipment	0.9	1.6	0.43	12
			0.95	55
T3 – ascend stairs with 65 mm diameter hose	0.7	1.2	0.9	75
T5 – descend stairs in BA	1	1.8	0.49	15.4
M – dismount appliance and don BA	88.1	145.5	202	>100
			236	>100
			56	17.9
			60	21

8.5.3. Discussion and Conclusions

At the outset of this research, the intention was to try and undertake a number of different fire ground field experiments at real buildings in an attempt to validate the FBIM against simulated real incidents. Unfortunately, most of the planned exercises had to be cancelled for a number of reasons and only two large-scale exercises were able to be undertaken with data collected. The two field experiments undertaken were completed at the same building using the same scenario simulating the search and rescue of two occupants on an upper level of a relatively complex building. Significant NZFS resources were employed to simulate real conditions in real time following NZFS SOPs as closely as could be expected. Whilst the results of the experiments were not completed under the same level of urgency as could be expected during a real emergency, the results have indicated a good agreement with an FBIM analysis of the building using a 95% confidence limit.

Due to the problems encountered with the data collection and other difficulties found when collecting data in and around a building undergoing such an exercise, and with the added problems of smoke logging, the data collected and results collated were not as comprehensive as originally envisaged. Future fire ground field experiments need to consider the implications of simulating smoke conditions with respect to the recording of fire-fighter activity times in smoke.

The exercises conducted identified a number of issues associated with the collection of data associated with such exercises and found that the use of video footage was the best way of capturing and analysing the data after the event.

As only two exercises were undertaken and only some of the results compared, further analysis and comparison of real incident training with FBIM analysis should be undertaken using NZFS data presented within this project to provide more comprehensive validation of the FBIM.

8.6. Application of FBIM within the Rural Environment

One limitation of the research undertaken and the findings of this report is that associated with the use of the FBIM in a rural environment. As with Australia, the vast majority of New Zealand consists of rural areas. However, the FBIM is typically used within urban areas and on significant developments that have the luxury of a greater level of fire service response than could be expected within a rural setting. Most of the Australian brigades are typically only applying the FBIM within an urban setting and although this issue was discussed, only urban FBIM examples were reviewed. The CFA is one brigade that has many remote and isolated buildings and has regular issues associated with fire service intervention, considering the long response times from volunteer stations associated with the rural environment.

Wright (84) provided an example of a hypothetical building design proposed within a rural environment. The example was used to highlight the deficiencies that could occur when a building design was based on the prescriptive requirements of the BCA but which is not provided with the level of service assumed to be provided within the BCA. Wright concluded that '*meeting the prescriptive requirements for this building may not meet the true objectives of the BCA*'. This situation is also true for any design in which the level of service or facilities available to the responding brigades is not in adherence to the assumptions on which the prescriptive codes were established as is the case in many parts of rural New Zealand.

The FBIM was developed to be applicable to the rural environment and contains both data and options covering all types of station response, including permanent, volunteer and composite stations. However, application in a rural environment is perceived to be more difficult and less well tried and tested. Although data exists, there are more unknowns in a rural situation and no guarantee of a fire-fighting response at all, as should otherwise be expected in an urban environment. These findings emphasise the importance of consultation with the relevant local fire services early in the design stage.

CHAPTER 9. A Risk-Based Probabilistic Analysis for Predicting Fire Brigade Intervention

The following chapter considers a risk-based FBIM analysis for a proposed building design taking into account the needs and effect of fire fighters responding to the building. The analysis has been undertaken based on the use of the data collected and proposed within this project. When an FBIM analysis is considered and used in performance-based designs, engineers and designers typically only consider an analysis which derives a single time value to reflect fire brigade operations. This is normally based upon an agreed margin of safety that is applied to the FBIM data, typically using the 95th percentile approach. However, there are no explicit margins of safety recommended to be used within the FBIM or published by any Australian brigades. These are normally agreed to during an FEB meeting in consultation with the relevant brigade. The FBIM chapter 4.3 discusses the issues surrounding the choice of incorporating either margins of safety into any analysis or using the percentile approach, and considers the issues that need to be addressed on a 'step-by-step' basis. The following analysis is given to provide an example of the results that can be derived using a probabilistic risk-based approach using the Monte-Carlo technique. The advantages of undertaking an FBIM analysis in this manner are shown and considered for each stage of the 'run strategy' so that the impact and expected fire brigade action can be addressed with respect to its effect upon the expected evacuation condition at that time or with respect to the proposed building's fire safety precautions.

9.1. Introduction

The analysis considers a 67-storey 232 m 'ultra' high-rise building consisting of a mixed commercial office and apartment development similar to one that was proposed to be constructed in Auckland, New Zealand in 2007. Whilst a building of this type and height has not been developed yet, it represents a building that would be 55 m taller than the closest similar building located in Auckland or anywhere else in New Zealand, excluding the Sky Tower. As this building far exceeds the height of any building in which the NZFS has experience operating in, the following analysis provides an initial assessment into the likely fire brigade intervention times that could be expected, should a fire occur within the upper levels of a building of this height. This building type has been specifically chosen to consider the data collected within this project and specifically that relevant to high-rise buildings, fire-fighter stair climbing speeds and NZFS appliance arrival times.

This analysis does not consider the detailed design of the proposed building and considers only the impact of fire brigade intervention based on a number of building design assumptions. The intention is to identify areas that could warrant specific consideration and detailed attention to understand any positive or negative effects of fire brigade intervention on the means of egress and needs of the responding fire fighters.

The analysis will consider three specific areas of fire brigade intervention and will assess the impact of individual fire safety precautions and their relevance to each of the three main fire brigade intervention or 'run strategies'.

- *Kerbside arrival*
  - *this includes the time for the fire brigade units to respond to a call and arrive at the fire scene, represented by FBIM Charts 1–4.*
- *Fire brigade arrival and set-up*
  - *the time at which the fire brigade will arrive at the fire scene, represented by FBIM Charts 1–11.*
- *Search and rescue*
  - *fire brigade arrival time including the time taken for search and rescue operations to be conducted, represented by FBIM Charts 1–12.*

Although a building of this height and type does not currently exist in New Zealand, taller buildings currently exist in Australia, such as the 88-storey Eureka tower. It is therefore considered quite likely that buildings with similar dimensions could become a reality in the future of New Zealand. The results of this type of analysis could be used to indicate potential areas for further investigation that may need to be considered by both the building designers and NZFS with respect to possible deployment decisions, if this type and height of building were to be constructed.

The Acceptable Solution C/AS1 (6) is not mandatory and thus only provides for one route to obtain building code compliance. C/AS1 states in the introduction that:

> *‘The methods given are particularly appropriate for simple, low-rise buildings.'*

Irrespective of this statement, C/AS1 does provide a design solution for a building of this height. Table 4.1 within C/AS1 provides for the fire safety precautions for buildings that exceed 58 m. There is no upper limit provided in C/AS1 which is considered to be outside of its scope. Assuming this building to contain a sleeping purpose group firecell SR with an escape height of 245 m, C/AS1 table 4.1/5 would require the following fire safety precautions.

- Type 7e Automatic fire sprinkler system with smoke detectors and manual call points where the e requires a Type 5 alarm system.
- Type 5 Automatic fire alarm system with modified smoke/heat detection and manual call points.
- Type 13 Pressurisation of safe paths.
- Type 15 Fire Service lift control.
- Type 16 Visibility in escape routes.
- Type 18 Fire hydrant system.
- Type 20 Fire systems centre.
- F60 Fire rating requirement.

Given that these fire safety precautions would also be required for a building with a 58 m escape height, it is unclear whether a building containing these fire safety precautions would also be appropriate for a building four times this height. As discussed in Chapter 5, some international building codes provide for additional and dedicated fire brigade facilities, such as additional staircases once buildings reach certain heights; for example, the UK Approved Document B (36) suggests that phased evacuation should be used for buildings in excess of 30 m and also that a stair should be discounted for any egress analysis as this will be used by the fire service. Following the World Trade Center disaster, NIST (75) also recommended that an additional staircase be provided for buildings that exceed 100 m in height dedicated to providing access for the emergency services into the building's upper levels. Therefore, this assessment will consider the issues associated with fire brigade intervention that can be readily identified using the FBIM analysis using a risk-based approach utilising Monte-Carlo analysis.

9.2. The Building

The building under consideration is a 67-storey, 232 m ‘ultra’ high-rise building consisting of a mixed commercial office and apartment development. The following assumptions will be considered within this analysis.

- No internal site travel is necessary on arrival at the building.
- The premises are assumed to be occupied as the fire occurs during the day and forced entry is not required.

- For simplicity, no hindrance factor has been included for occupants making egress against the flow of fire fighters entering the building or climbing stairs.
- No time for any security procedures will be included as a fire warden will be assumed to be present. The time to communicate with the warden will be taken as 30 seconds.
- It is assumed that a compliant fire alarm, sprinkler and fire hydrant system is installed within the building.
- Fire fighters will take the lifts and climb to the 66th floor, connect hoses to the fire hydrant system and make entry to the top floor level at the head of the stairs in accordance with NZFS SOPs.
- A travel distance of 6 m per level per flight of stairs is assumed.
- The fire hydrant system is permanently charged and no additional time component associated with charging the system is included.

9.3. Analysis

The analysis will consider the expected NZFS response to a high rise building incident in line with NZFS Operational Instructions and high-rise procedures, an example of this on which these scenarios are based is given in Appendix J. The results presented are based on a Monte-Carlo analysis using 10,000 iterations and the Latin Hypercube sampling method.

The analysis will consider both sprinkler and smoke detectors as a means for detecting the fire and alerting the NZFS. Table 50 shows a breakdown of each activity considered within the analysis and identifies the FBIM charts and tables used including the distributions used in @Risk for each individual activity. Where data collected as part of this research has been used, this is identified by the relevant FBIM Table letter and appended 'NZ' e.g. **A** - NZ. These individual components are discussed in greater detail in the following section.

Table 50 Individual high-rise FBIM analysis

	FBIM chart reference and activity	FBIM data table	Distribution used
1	**Time taken for initial brigade notification sprinkler detection scenario**		
	Sprinkler activation		RiskUniform (295,332)
	Time to depressurise system and activate alarm	**A** - NZ	RiskUniform (60, 360)
	Time taken for initial brigade notification smoke detection scenario		
	Smoke detection		RiskUniform (33, 35)
	Time delay for alarm verification 30 s	**B** - NZ	
2	**Time taken to dispatch resources**		
	Time to relay dispatch information by NZFS CAD systems	**D** - NZ	RiskLognorm (26.8,14.6, shift -−0.85)
3	**Time taken for fire fighters to respond to dispatch call**		
	Time to dress, assimilate information and leave station – CBD	**E** - NZ	RiskLoglogistic (−308.3,384.7,25.5)
4	**Time taken for resources to reach fire scene (kerb side)**		
	Appliance 1 – Auckland CBD – 1 km	**F** - NZ	RiskNormal (35.7,11.5, RiskTruncate (12,100))
	Appliance 2 – Auckland CBD – 2 km	**F** - NZ	RiskNormal (35.7,11.5, RiskTruncate (12,100))
	Appliance 3 – Auckland CBD – 3 km	**F** - NZ	RiskNormal (35.7,11.5, RiskTruncate (12,100))
5	**Time taken for initial determination of fire location**		
	Time to communicate with warden – 30 s	**H**	
	Time for information gathering from a fire alarm panel complying with NZS 4512 – 30 s	**L** - NZ	
6	**Time taken to don safety equipment and gather necessary tools**		
	Time to dismount fire appliance and don BA	**M** - NZ	RiskNormal (74, 5, RiskTruncate (56,850))
	Time to remove high-rise pack or similar	**P**	RiskNormal (13.46, 5.96, RiskTruncate (5, 30))
7	**Time taken to assess fire**		
	OIC does not travel to set-up area		
8	**Time taken to travel to set-up area**		
	Time for any security procedures – none	**G**	

9	**Time taken for fire-fighter travel to level 66**		
	Side hung door – 10 s	**J**	
	Horizontal travel time from appliance to front lift lobby of building approx 40 m	**Q**	RiskNormal (1.4,0.6,RiskTruncate (0.28,3.33))
	Fire-fighter vertical travel speeds		
	using lifts fireman's lift – 231 m at 9.14 m/s	**R -** NZ	
	loading time 30 s	**R**	
	using stairs fire-fighter stair travel speed up 396 m	**T** - NZ	RiskNormal (0.6,0.15, RiskTruncate (0.28,0.82)
	rest breaks – 16.5	**T** - NZ	RiskUniform (0, 60)
	Ascend stairs with 65 mm diameter hose – 24 steps	**T**	RiskNormal (0.71, 0.31, RiskTruncate (0.15, 1.4))
10	**Time taken to set up water for initial fire-fighter protection**		
	Time taken to setup water for initial fire-fighter protection less than time taken for fire fighters to reach fire floor		
11	**Time taken to set up water supply requirements**		
	Connect hose to hydrant outlet and charge to fire floor – 2 lengths	**V**	RiskNormal (59.6, 37.9, RiskTruncate (15, 163))
	Time to search for external water source – 1 length – 30s	**W**	
	Connect hose from street hydrant to appliance – 1 length	**V**	RiskNormal (45.3, 17.1, RiskTruncate (17.5, 80))
	Connect hose from appliance to hydrant inlet and charge – 1 length	**V**	RiskNormal (75.4, 23.8, RiskTruncate (38, 99))
12	**Time taken for search and rescue**		
	Time to search area (secondary search) 1000 m^2	**Y**	RiskNormal (0.6, 0.1, RiskTruncate (0.1, 0.3))

9.3.1. Fire Brigade Arrival and Set-Up

The term 'kerbside arrival' is taken from the time of ignition of the fire until the time the first appliance arrives at the building, and is considered within FBIM charts 1-4. The analysis first requires information relating to the detection of a fire. Assuming that both smoke detection and sprinklers are likely to be provided in some form of combination, the analysis considers the times for both sprinklers and smoke detectors to detect a fire and provide an alert. The parameters for the sprinklers and smoke detectors are given below in Table 51 and are based on the criteria given in the proposed DBH performance framework for fire safety that, if adopted, would provide a compulsory methodology for performance-based fire engineering designs to prove compliance with the fire safety requirements of the NZBC (21).

Table 51 Detector criteria used within FBIM analysis

Detector criteria	
Commercial sprinklers	**Smoke detectors**
RTI = 95 C = 0.4 T_{act} = 68 ^{o}C Radial distance = 2.8 m Depth below ceiling = 20 mm	Optical density at alarm (1/m) = 0.097 Detector sensitivity (% per ft) = 6.6 Characteristic length (m) = 15 Radial distance = 7 m Distance below ceiling = 0.025 mm

The sprinkler and smoke detector parameters have been used within the BRANZFIRE zone model version 2009.1 (85) to determine a predicted range of response times given an assumed 3.5 m room height and a medium t^2 fire growth rate. As the layout of the building is unknown, a fire could occur within a small enclosed area or large open room providing for a range of potential detection times. Two detector scenarios have been included, considering a small (5 m x 5 m) room and a larger (20 m x 20 m) area with no ventilation effects to represent a range of possible detector response times. Using a range of detection times also allows for the potential effect of different fire growth rates that would also have a significant bearing on the possible detection times. The detector activation times were calculated to be between 295 and 332 seconds, respectively, for the commercial sprinkler and 33 and 35 seconds, respectively, for smoke detector activation using the NIST ceiling jet algorithm. As these activation times were considered representative for this type of building, they have been used in the analysis, proposed as uniform distributions with these values as the considered minimum and maximum activation times.

For consideration of NZFS response and arrival times, the building has been assumed to be located within central Auckland, New Zealand. The distance to the closest permanently manned career fire station using the shortest trafficable route has been assumed to be 1 km.

Figure 70 below shows the predicted kerbside arrival time considering 10,000 iterations assuming the NZFS is alerted by either brigade-connected automatic sprinkler or smoke detection systems.

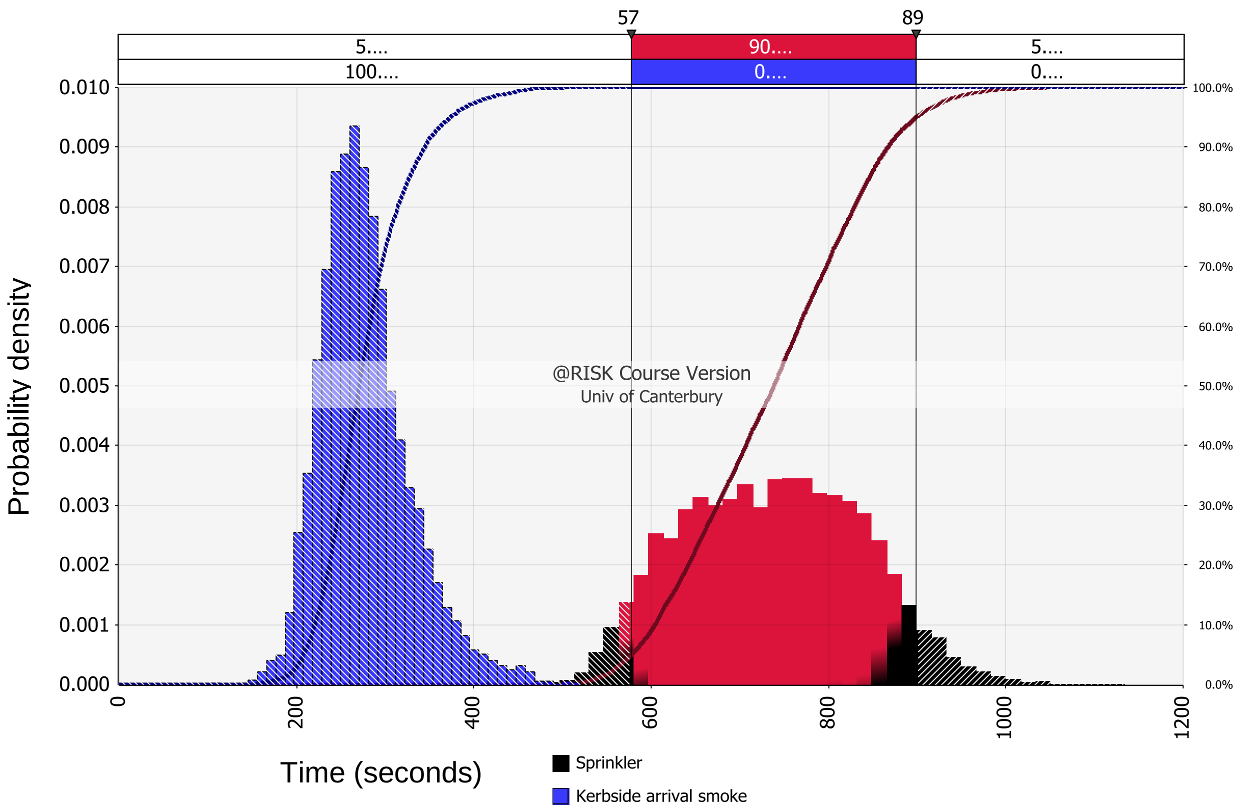


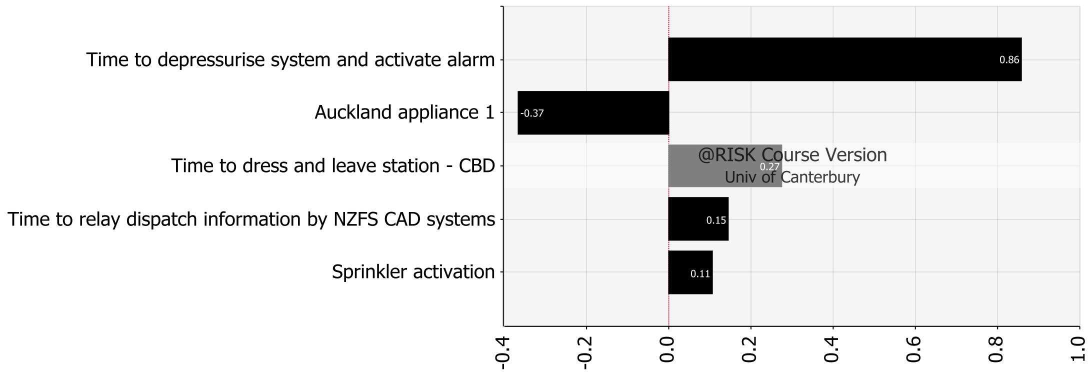
Figure 70 Predicted kerbside arrival distributions considering sprinkler and smoke detector system activation and notification

Table 53 provides a summary of the expected kerbside arrival times. As would be expected, arrival of the closest responding fire appliance is likely to be far quicker when responding to detection from a smoke detector than from sprinkler activation.

Table 52 Predicted kerbside arrival times (seconds)

Detection type	Mean	Minimum	Maximum	5th percentile	95th percentile
Sprinkler	737	463	1134	578	899
Smoke detector	277	104	521	207	373

The difference in calculated arrival times is clearly evident with the maximum predicted arrival time for smoke detector activation considering 10,000 iterations occurring less than a minute after the minimum expected arrival time for sprinkler activation. Figure 71 shows the regression sensitivity analysis for the calculation inputs graphically displayed using tornado graphs. The graphs rank the inputs in accordance with their impact on the output. As can be seen for the sprinkler scenario, the input *'time taken to depressurise system and activate alarm'* has by far the biggest impact on the predicted kerbside arrival time. Further examination of this input value suggests that investigating and increasing the confidence in this input could make a significant difference to the predicted NZFS kerbside arrival time.



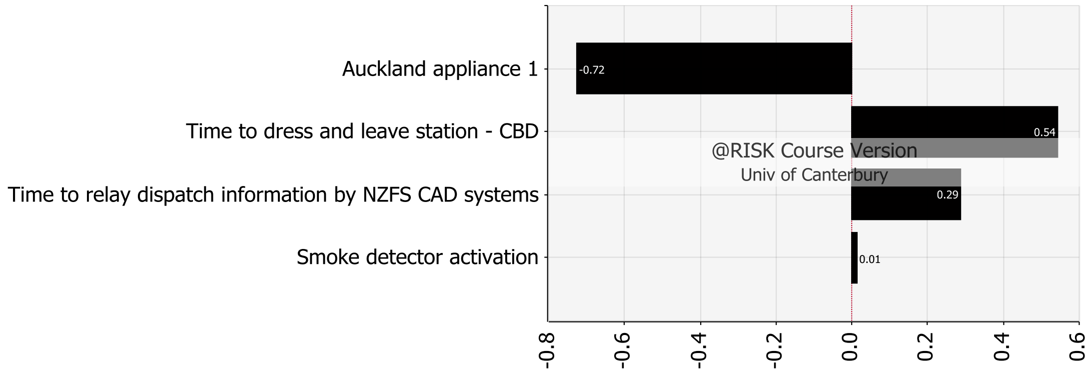


Figure 71 Regression sensitivity analysis for the kerbside arrival considering notification by sprinklers (top) and smoke detectors (bottom).

9.4. Fire Brigade Arrival and Set-Up

The time components for the fire brigade arrival and set-up are considered through FBIM Charts 5–11. Two assessment options are considered for this analysis including a response from fire fighters using lifts and the stairs assuming the data proposed in this project.

This analysis assumes that two fire fighters will remove hydrant riser packs from the appliance and, with the officer in charge of the appliance, make their way to the floor below the determined location of the fire to set up and start fire-fighting operations. Meanwhile and concurrently, the pumping appliance operator/driver will set up water supplies and will, on request, charge the hydrant system and sprinkler system if required. For this part of the analysis, it is assumed that a street hydrant is located within 30 m of the parked appliance and a single length of feeder and supply hose is used to supply water to the appliance and to charge the hydrant system. The predicted time taken to setup water supply requirements outside the building is shown in Figure 72. The maximum predicted time to set up the water requirements is less than the minimum time predicted to reach the fire floor using any method at 208 seconds and 182 seconds for a 95 percentile confidence limit. This time component can be discounted from further consideration as it occurs concurrently and would be completed in time to ensure water was available when required by the fire fighters at the fire floor.

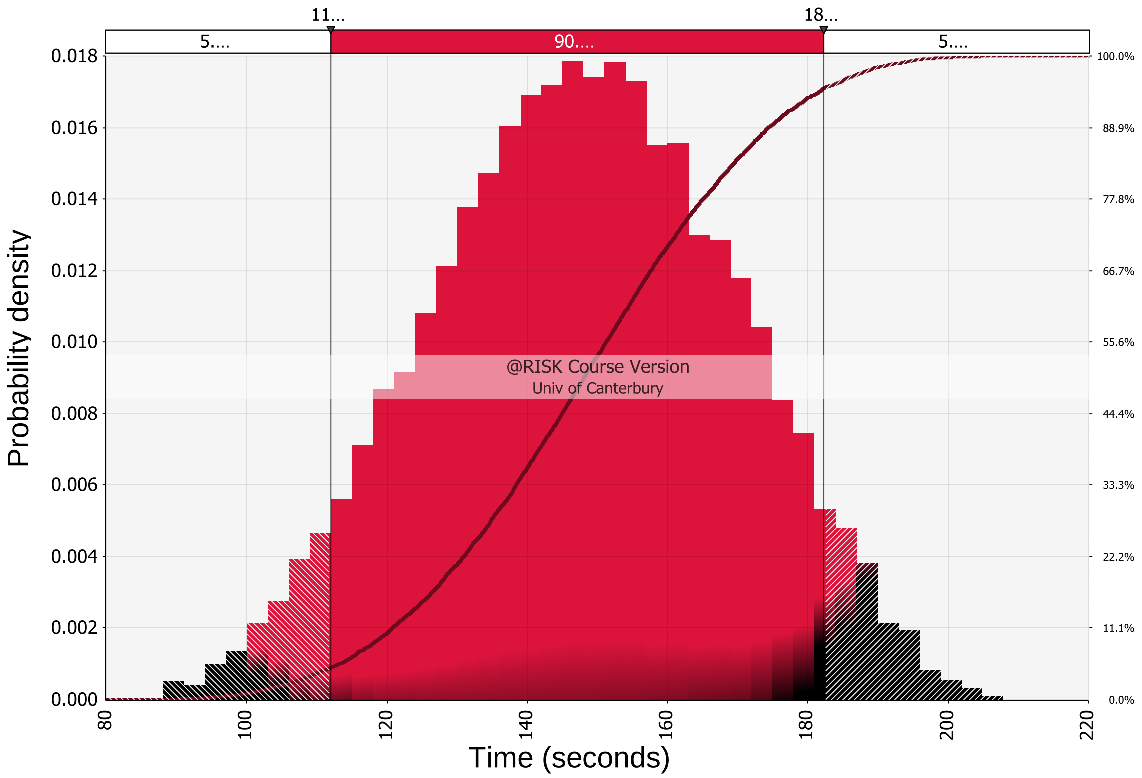


Figure 72 Predicted distribution of the times taken to set up water supply requirements outside the building, shown with a cumulative overlay.

The calculated times taken to reach the fire floor with charged hoses using both lifts and the stairs are shown in Figure 73 with the times given in Table 53.

Table 53 Predicted internal response times using lifts or stairs (seconds)

Response type	Mean	Minimum	Maximum	5th percentile	95th percentile
Stairs	1076	382	1849	611	1535
Lifts	404	271	640	307	522

As would be expected, the fire-fighter response times to the fire floor are significantly quicker when comparing a response using the lifts compared with fire fighters using stairs.

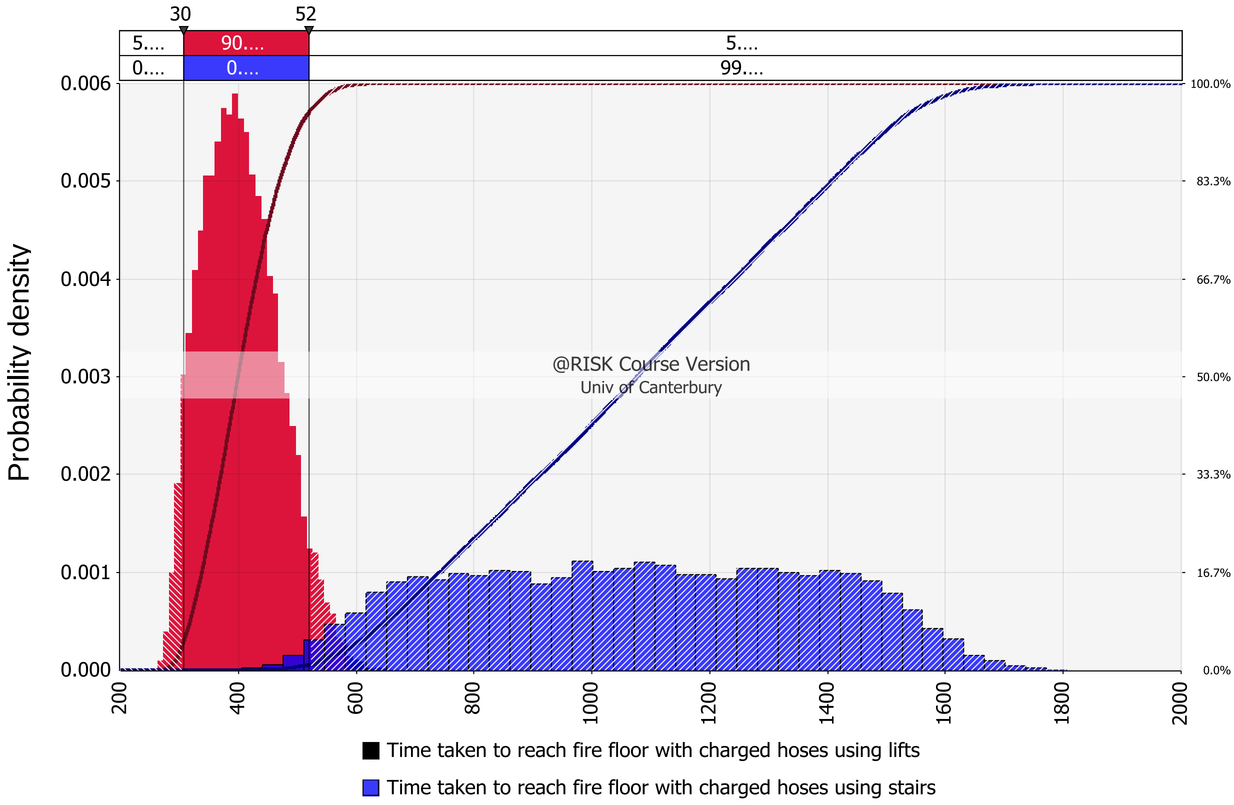


Figure 73 Internal response time distributions using lifts or stairs (seconds) shown with a cumulative overlay

Regression sensitivity analysis for the expected response time to the fire floor dependent upon the use of lifts or stairs is shown in Figure 74. When using lifts to reach the 65th floor, the time taken to connect the hose to the hydrant outlet and make entry to the 66th floor level has the largest overall impact on the arrival time, whereas the rest break parameter has the largest impact followed again by the time taken to connect the hose to the hydrant outlet from the floor below when stairs are used.

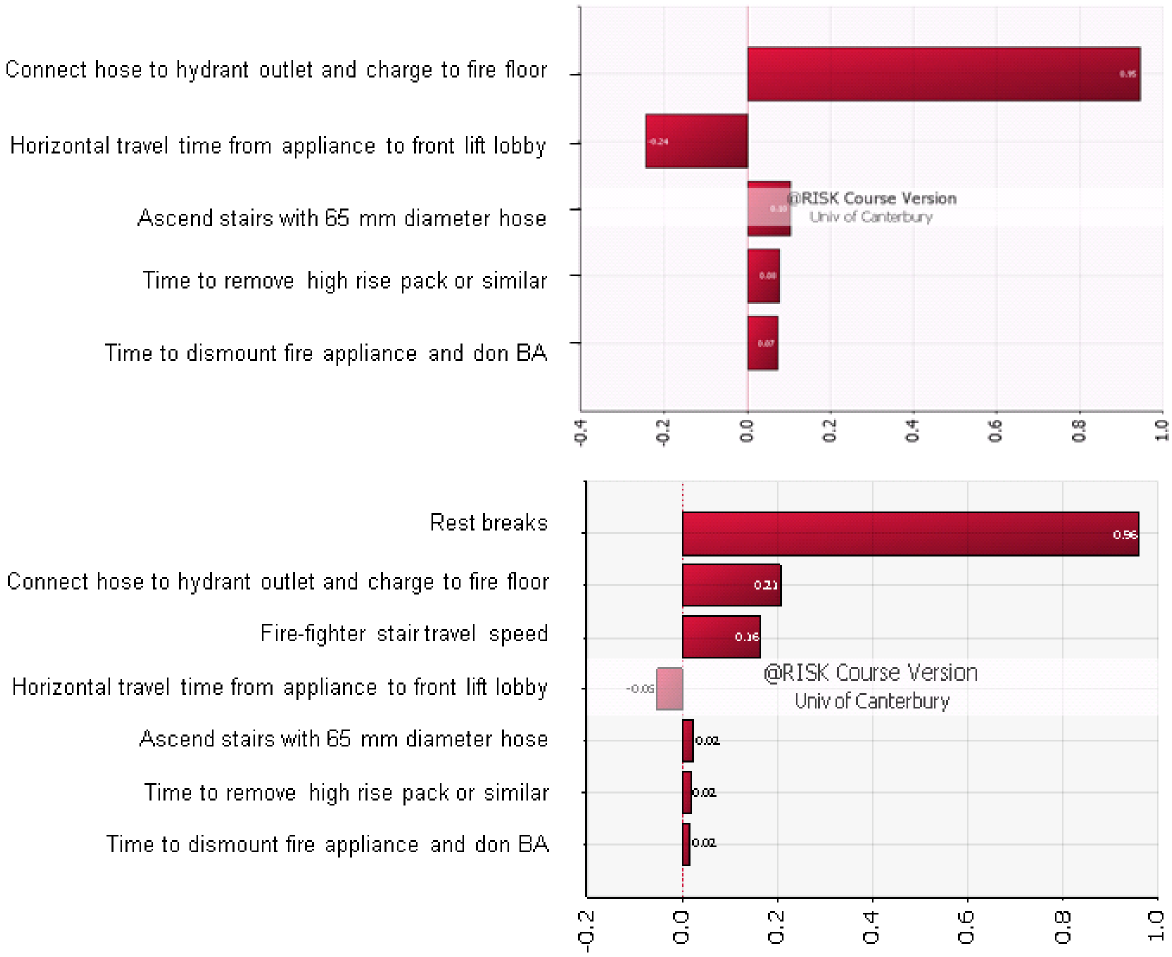


Figure 74 Regression sensitivity analysis for the internal response using lifts or stairs

9.4.1. Total Predicted Time to Start Fire-Fighting Suppression Operations

The two scenarios addressed above have not yet considered the total time taken given the four possible options that can now occur. The following results present the overall times for the four options assuming either detection by a sprinkler or smoke detection system and with fire fighters responding using a lift or the stairs. Figure 75 shows the predicted distributions with the times presented in Table 54. The analysis indicates a wide variation of predicted times dependent on the method of detection and alert and whether stair or the lifts would be used to reach the fire floor. The minimum predicted time before suppression operations could be expected to occur could be as little as 455 seconds with the largest time calculated as 2674 seconds, depending on the specific nature of detection and response.

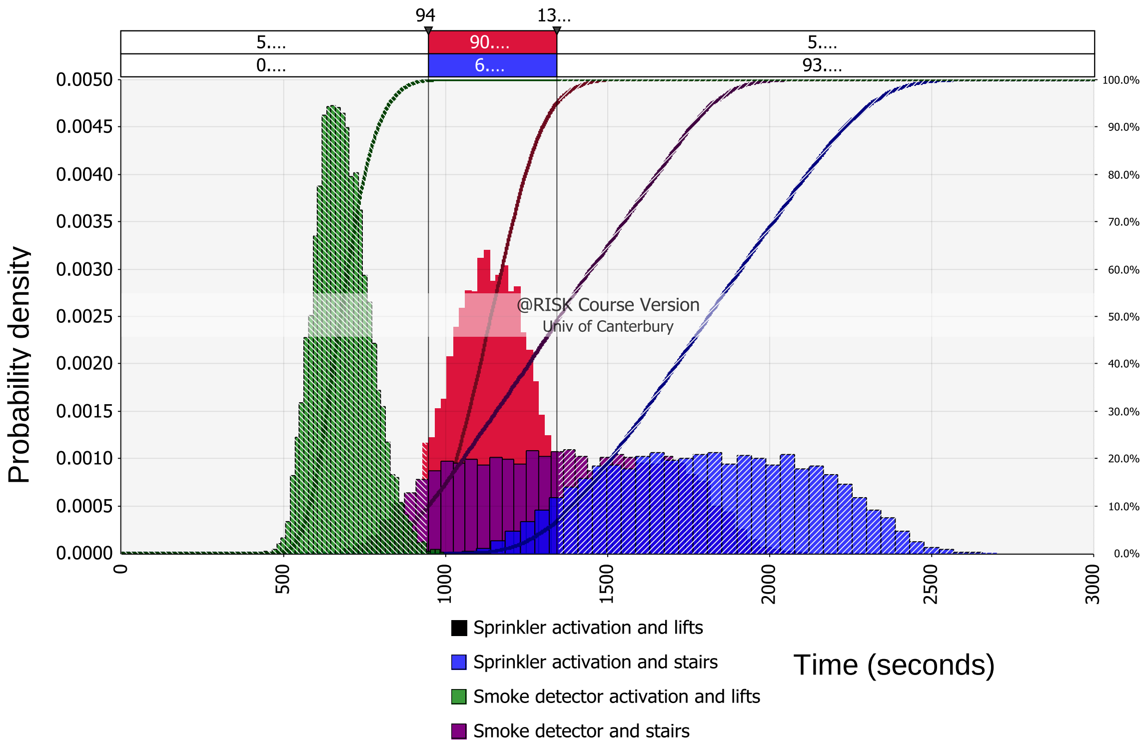


Figure 75 Overall response time distributions using lifts or stairs and given notification by sprinkler or smoke detector activation (seconds)

As can be seen, the times taken for fire fighters to respond to this type of building and to start suppression operations can be considerable. Considering only a 5% confidence value returns a prediction of as long as 10 minutes for the fastest intervention scenario. Where fire fighters could be expected to use lifts in a smoke detector scenario, times as long as 14 minutes are returned when a 95 percentile confidence limit is applied.

Table 54 Predicted total response times to start suppression operations (seconds)

Response type	Mean	Minimum	Maximum	5th percentile	95th percentile
Sprinkler activation and lifts	1142	797	1551	946	1342
Sprinkler activation and stairs	1813	917	2701	1309	2314
Smoke detector activation and lifts	682	437	995	556	826
Smoke detector activation and stairs	1353	607	2118	878	1823

9.5. Search and Rescue

The times associated with search and rescue operations will vary significantly upon the size of each floor and its complexity as well as whether conditions on the fire floor would be tenable for fire fighters. Search and rescue operations are more complicated within high-rise buildings as fire fighters will attempt to search and at least make an examination of the floors above the fire, should the fire require fire suppression operations to occur. The purpose of this type of search is to ensure that no occupants remain above the level of the fire and to make an assessment of any fire spread occurring throughout the upper levels. The times taken for such operations in high-rise buildings requires that significant support operations and resources be put in place to replenish air supplies, move equipment and to rotate fire fighters, etc. These operations may occur concurrently with fire suppression operations on the upper levels and will be heavily dependent on the layout of stairs and the ability to establish control points inside the building. An example of NZFS high-rise procedures is given in Appendix J to highlight the responsibilities of each arriving crew and the tasks expected of them at a high-rise building incident.

Significant resources would be required to be factored into an FBIM analysis if a full search and rescue analysis was desired so this assessment has not included analysis of this particular component. However, assuming that the building contained a floor area of 1000 m^2 and using existing Australian FBIM data, the FBIM predicts that an average time of 55 minutes could be expected for fire fighters to undertake a secondary search, assuming the use guidelines and standard search techniques in smoke-logged conditions. This is a significant time component for consideration of people remaining within the building during a fire event and consideration of this length of time on the specification of the building's structural and internal fire separation requirements is necessary.

9.6. Results

The predicted times taken for fire fighters to respond to a fire within a 67-storey building are long and are heavily dependent upon the method of fire detection, notification and whether fire fighters choose, or would have any choice as to, whether they made access to the fire floors using lifts or stairs. For a 95th percentile confidence limit, the maximum predicted times taken were between 14 and 40 minutes, dependent on the method of detection and internal response method. For a best-case scenario assuming a fifth percentile confidence limit, times ranged from 9 minutes to 22 minutes. This analysis did not consider the impact of occupants escaping at the same time as fire fighters were entering the building. No specific egress analysis has been undertaken, however it has been shown that fire fighters would be arriving at the building and would be ready to start making entry into the building and potentially impacting with occupants trying to make egress after as little as three minutes for the fastest predicted arrival time with a fifth percentile confidence limit. However, this time could take as long as 15 minutes for the longest scenario, given a 95th percentile confidence limit. What is apparent, however, is that it is very likely given the height of the building that fire fighters would be arriving at the building whilst occupants are trying to evacuate. Consideration of the likely effects on both the occupants trying to evacuate and responding fire fighters trying to make access to the fire floors should be considered.

The fire-fighter response times to the building given the different scenarios have also been shown to form a less significant part of the overall intervention time, contrary to conventional thinking. Considering average values, the time taken for the fire service to arrive at the building ranges from 20%, to approximately 67% of the time component. When only the fire-fighter response time is considered, that being once the NZFS are notified of a fire, this percentage reduces further with the resulting times ranging between 11% and 19% of the overall time taken before fire fighters could be expected to be in a position to start suppression operations. If the overall fire brigade intervention time to complete operations were considered, it is likely that the response time of the NZFS would be found to be insignificant compared with the other tasks required to take place.

9.6.1. Regression Analysis

Regression sensitivity analysis can be used to identify the inputs that have the most significant impact to the output and allow for a better understanding of the inputs that are driving the results. The length of the bars represents the degree of correlation with the output variable. They can identify areas that should be investigated further if refinement, increased confidence or scenario adaption's need to be considered if the scenarios identify results that are not acceptable.

Figure 76 shows the regression sensitivity analysis for the scenario considering sprinkler activation and lifts. This identifies that the time taken to depressurise and activate the sprinkler system has the largest impact on the result. It also identifies that further investigation of the times taken for fire fighters to connect hoses to the hydrant and make access to the fire floor could be useful when considering alterations to this input value.

Options such as the provision of appropriate floor lobbies and additional protection to the staircase and hydrant outlets could allow fire fighters to make access directly from the hydrant on the fire floor, reducing this time component, for example.

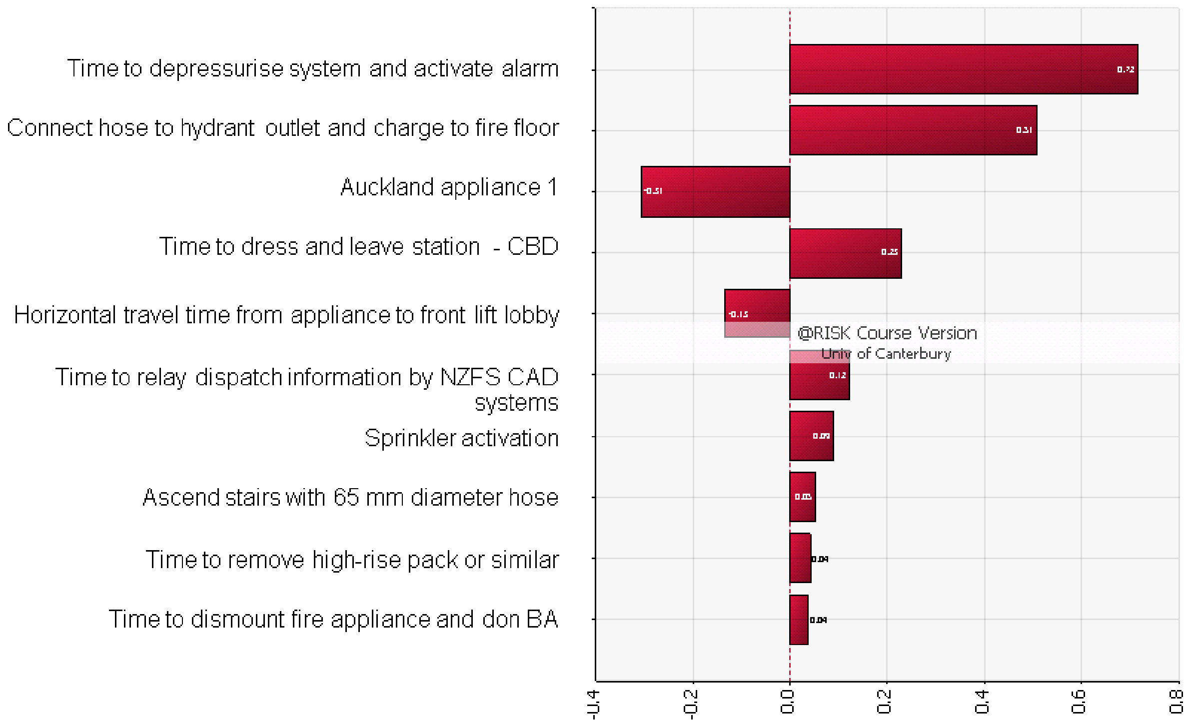


Figure 76 Regression sensitivity analysis for the scenario considering sprinkler activation and lifts

Figure 77 shows the regression sensitivity analysis for the scenario considering sprinkler activation and use of stairs. This analysis of the inputs to this scenario identifies that the rest breaks taken during the stair-climbing component has the largest impact on the result. Research undertaken as part of this project has identified the significant problems associated with the difficulties of fire fighters climbing high rise buildings and the need to factor in appropriate times for rest breaks. It is also possible that a building of this height is beyond the physical capability for fire fighters to respond using stairs and mount suppression operations within a heated fire compartment safely. This regression analysis identifies that the second and third most important inputs are again the sprinkler activation time and the times taken for fire fighters to connect hoses to the hydrant and make access to the fire floor.

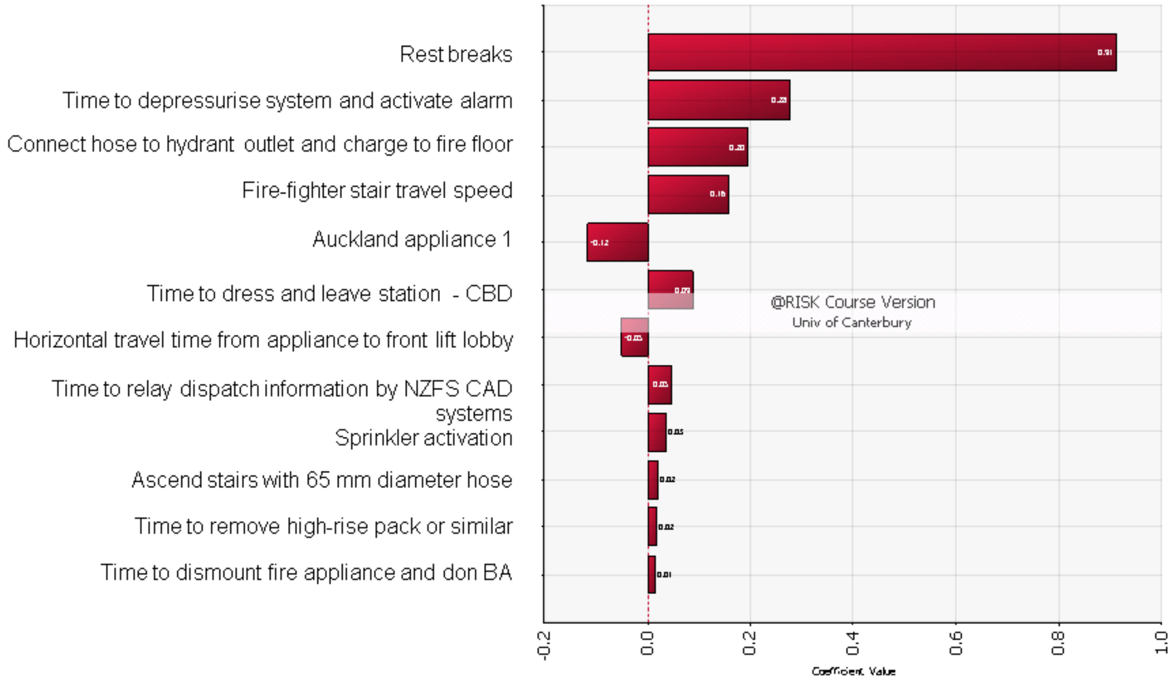


Figure 77 Regression sensitivity analysis for the scenario considering sprinkler activation and use of stairs

Figure 78 shows the regression sensitivity analysis for the scenario considering smoke detector activation and the use of lifts. The analysis of the inputs to this scenario identify that those having the largest impact on the results are those that are outside of the control of the designer and mainly concern fire-fighting tasks. This indicates that there is probably little potential for further refinement of this scenario except to identify the need to ensure that the assumptions are appropriately considered within the design. Placing reliance on fire fighters using the lifts and that detection and notification is given by smoke detection may require additional specification to ensure increased reliability or to undertake a potential failure modes analysis of these to assess the likelihood of these facilities not being available during an incident.

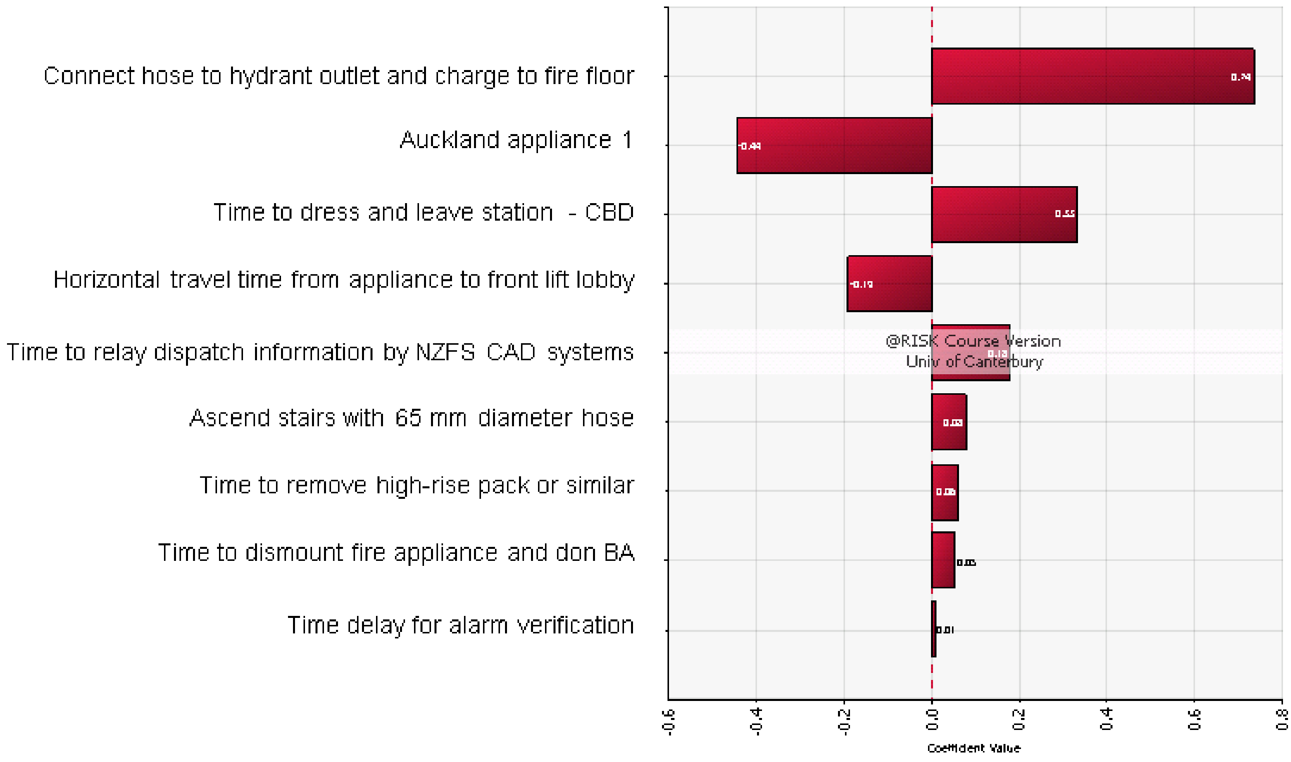


Figure 78 Regression sensitivity analysis for the scenario considering smoke detector activation and lifts

Again, the regression sensitivity analysis for the smoke detector activation scenario identified that the main inputs relate to fire-fighting tasks. As expected, considering the use of stairs, the distribution associated with rest breaks is the most significant input affecting the scenario output.

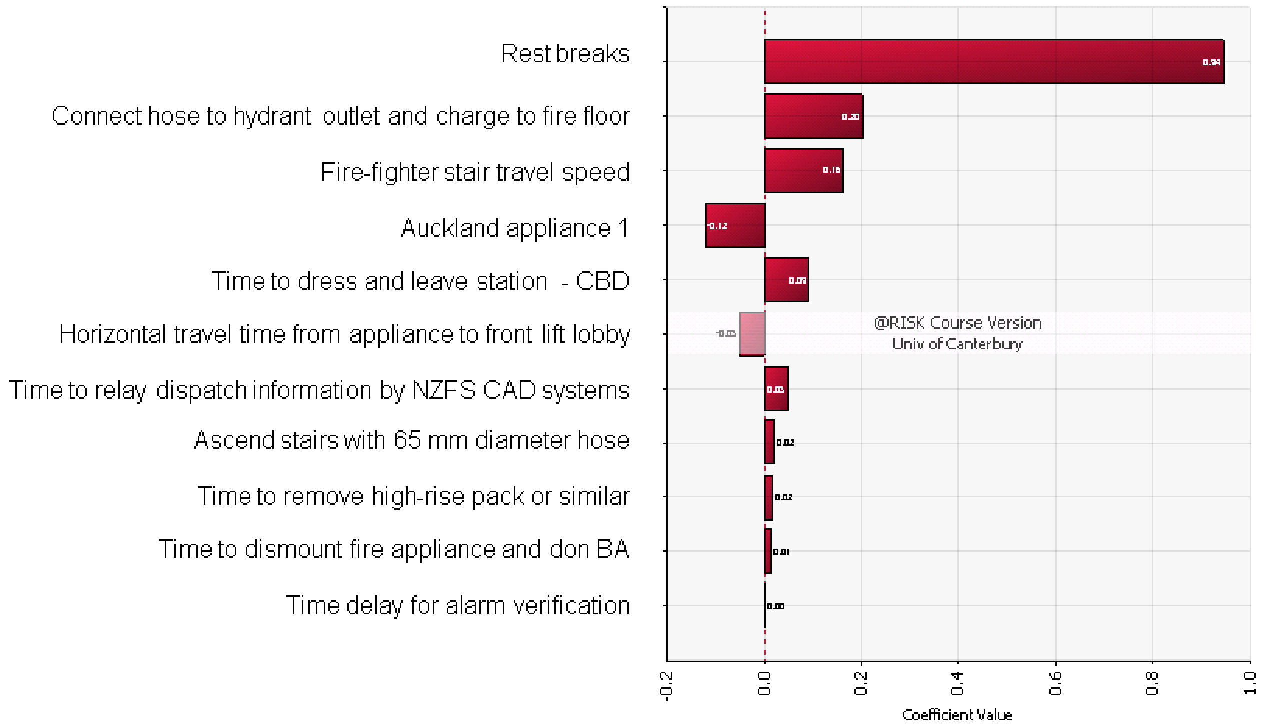


Figure 79 Regression sensitivity analysis for the scenario considering smoke detector and stairs

The full scenario simulation output reports from @Risk for these results are provided within Appendix K for review.

9.7. Discussion

The results generally identify that there could be relatively long intervention times associated with fire-fighting operations in a high-rise building such as the one considered here. Consideration of the results of this FBIM analysis should be used to identify their impact on the proposed building design from a holistic perspective. When considering the performance requirements of the NZBC and how these are demonstrated, the FBIM results could be used in conjunction with other recognised fire engineering methodologies, such as fire growth and evacuation modelling, to demonstrate that the building can meet all of the code's performance requirements. The results can also be used to identify other factors that may be of importance such as the level of property damage that could be expected due to smoke or water damage from the activation of sprinklers when considering the delayed fire-fighter response times.

As identified here, fire station location and the travel time to a high-rise building is almost insignificant considering the overall intervention time. This is contrary to the general perception of many emergency services agencies and the public.

When considering the prescriptive and performance requirements of the Building Code that would be of most relevance to this type of high-rise building, the following main points could be worthy of further consideration.

- Detection and notification to the fire service should be as early as possible and be from smoke detection systems located throughout the building. As C/AS1 only requires the full building alarm and fire brigade to be notified by sprinkler activation, consideration should be given to the provision of notification of the brigade by activation of the smoke detection system. Specific design solutions would need to be considered to mitigate the increased potential and impact of unwanted alarms if smoke detection was to be used to notify the NZFS.

- Although fire service lift control would be expected within this height of building, there are few specific requirements prescribing how many lifts are made available, their configuration and the level of protection afforded to them. Further consideration should be given to the number of dedicated fire-fighting lifts to be provided and their reliability if they are assumed to be used within an analysis.

- Structural fire ratings may need to be specifically considered given that there are scenarios that predict that fire fighters could be in the building for a substantial length of time. As C/AS1 only requires a fire rating of 60 minutes, this could be shown to be too low for a building of this height, even for a sprinkled fire scenario.

- The evacuation strategy to be adopted needs to consider the impact of fire fighters attempting to make entry to the building at the same time as occupants making egress.

- It is necessary to further investigate the logistics and time associated with the fire fighters closing off an exit stair for fire-fighter equipment staging during an emergency evacuation. The provision of appropriate facilities to control occupants within the exit stairs who are descending from floors located above the fire floor needs to be considered. The effect of occupants needing to immediately leave their chosen exit stair when that stair has been closed off by fire fighters, and issues associated with transferring back into other floors or into the nearest available stair need to be considered.

- Information is critical during a fire emergency and data from equipment such as remote field devices and television or security cameras in strategic positions including lobbies and staircases could be invaluable to allow real time assessment of the fire and evacuation.

- The lifts needs to be protected against smoke and water ingress, otherwise they may not be available, forcing fire fighters to use the stairs.

- Both lift and stairway shaft pressurisation should be considered.

- If lifts are to be used for staged occupant evacuation these need to be considered separately to dedicated fire-fighting lifts and be located in separate shafts from those located in the evacuation zone of fire origin to mitigate the potential for water damage.

- Emergency and redundant back-up power supplies for the lifts needs careful specification and consideration should be given to it being powered from an external emergency power source.

- Consideration for the provision of dedicated refuge floors for both occupants to rest and to allow the fire service to stage operations and to provide forward control points in locations outside of stairs should be considered for buildings of this height.

- Examination and potential modification of fire-fighter procedures may need to be considered in line with the specific fire safety precautions and geometry, stair and lift configurations of the building.

9.8. Conclusion

Use of a risk-based FBIM analysis provides for a clear and transparent method of factoring in the expected fire-fighter intervention within a building design. This allows for identification of the expected times associated with the most important factors that can affect both the evacuation of the building occupants and the fire fighters reaching the location of the fire, and the times associated with tasks that may need to be undertaken during a fire incident. A sensitivity analysis of fire brigade intervention can then be undertaken with results scrutinised considering the building's proposed fire safety features with identification of the most important inputs. The results can then be easily depicted and scrutinised as a probability function allowing identification and potentially improvement of fire brigade intervention through different design choices and fire service operational techniques. For building design purposes it is necessary to identify the most important input variables that have the greatest affect upon the design of any egress systems and fire brigade intervention facilities and ensure that those with the greatest effect upon the output are assessed in more detail. This allows for further refinement or complete substitution for different or additional facilities.

The outcome of this type of an analysis may require the consideration of additional or alternative fire safety features and similarly additional or alternative operational procedures to be adopted. These can then be tailored specifically to the building, producing an improvement to both occupant and fire-fighter life safety as well as decreasing property damage and improving outcomes for all the community.

CHAPTER 10. Future Fire Brigade Intervention Data Requirements

FBIM data collection is not complete and further data as well as further analysis to identify any additional differences between the NZFS and Australian practices should be undertaken. There were no significant differences found between fire appliances, equipment or procedures used within the Australian brigades and those in use by the NZFS that would have an appreciable effect upon the outcome of an FBIM analysis using the current data. However, some aspects of the data collected so far have been limited with respect to actual fire-fighter activity data and this part of the research should be continued.

Differences between some volunteer and career fire-fighter practices and equipment such as the use of seat-mounted BA and locker-mounted BA have been identified, which should be considered within an analysis. Differences between the use of flaked and rolled hose and differences between hose diameter, lengths of hose and coupling types have also been identified between the Australian and NZFS equipment. However, some of these differences have been found to have or are suggested to have little or minor effect on the outcome of an FBIM analysis.

This project introduces many opportunities for further study including the following.

- Times associated with the operation and activation of automatic detection and suppression systems that comply with the New Zealand standard have not been collected as part of the project. A uniform distribution has been recommended based on advice provided by recognised sprinkler experts. However, specific research into the time between activation of any sensing element and notification of the NZFS should be undertaken to investigate what delays, if any, may be present and what relationship these delays have with respect to the design of the systems. Such research would also be useful for understanding its effect upon occupant notification and the potential effect it may have upon evacuation analysis.

- The least well understood area for the application of the FBIM is the rural environment. The long response times associated with rural and some volunteer responses can result in fire brigade responses that are significantly longer than would be expected within a typical urban scenario. The issues of fire-fighter life safety and the performance requirements of building codes in these environments should be specifically investigated to identify if the performance requirements or expectations and reliance on fire brigade response require a different approach to the urban environment.

- Education about the FBIM should be provided and be available to those within the building industry involved with building designs that do not follow prescriptive requirements.

- Other uses of the FBIM should be investigated to identify its relevance for use in:
    - post-incident analysis and fire investigation;
    - fire-fighter training including deployment decision training and its use within computer simulation models such as VectorCommand.

- Further fire ground field experiments at real buildings should be undertaken to validate the FBIM further and to identify further refinement of the model.

- Further data analysis for appliance travel speeds within the larger cities based on larger data sets could be undertaken to identify if any trends similar to those found in previous studies exist and whether any can be described for rural areas. Further scrutiny of the data separated into evening and daytime responses could be warranted to identify any relationships that might exist.

CHAPTER 11. Conclusions

The following conclusions have been made from the research conducted as part of this project.

- Analysis of building consent applications submitted to the NZFSC for review has identified a common trend for fire-fighting facilities and the needs of responding fire fighters to be ignored within fire designs utilising alternative or performance-based methods. Specifically, the following findings can be summarised.

    - Within all responses provided by the NZFSC, recommendations regarding fire-fighting facilities were made in 47% of responses. Reponses containing advice on fire hydrants and attendance points including FAP locations were made in 21% and 25% of responses, respectively. In 16% of all submissions reviewed, no information at all regarding fire-fighting facilities was provided, but was considered necessary by the NZFS to demonstrate compliance with the NZBC. In 67% of the responses provided by the NZFS advice was given stating that the submissions contained insufficient information to demonstrate compliance with the NZBC and recommended that further information be supplied.

    - For new buildings containing alternative fire-engineered solutions, the findings indicate that the NZFS made recommendations regarding fire-fighting facilities in 63% of responses, and for fire hydrants and attendance points, including FAP locations, in 31% and 37% of responses, respectively. In 23% of all submissions for new buildings, no information at all regarding fire-fighting facilities was provided. In 66% of the memorandums produced by the NZFS, advice was given stating that the documentation submitted for review contained insufficient information to demonstrate compliance with the NZBC.

- Fire-fighting intervention requirements of the NZBC and current NZ legislation have been identified as being potentially deficient when compared with other available fire-fighting intervention methodologies and performance-based building codes available internationally.

- The collection and analysis of the data required to support an FBIM analysis is presented and considered sufficient to permit its use within the New Zealand context and within a probabilistic risk assessment methodology. Where insufficient data specific to the NZFS has not been able to be collected, existing Australian FBIM data has been validated against NZFS procedures and equipment or discussed with regards to its relevance, and is recommended for use until further data is collected.

- Verification and validation of the FBIM with fire ground field experiments has been undertaken and shown to compare well with the existing FBIM computer program using existing FBIM data.

- Validation of specific FBIM data against emergency incidents that have been attended during this research has also established confidence in the use of the data collected and the FBIM methodology.

- An FBIM analysis for a high-rise building is presented utilising the data collected within this project using a risk-based probabilistic approach and Monte-Carlo analysis methods. This analysis has identified the advantages of using the FBIM and probabilistic analysis over the traditional percentile approach, to identify areas that warrant further scrutiny to improve the fire engineering design and tailor the building's fire safety features specifically to the building.

- The data presented as part of this research is recommend to be presented within the next revision of the FBIM manual so that it can be made available as part of the FBIM proper.

The FBIM has been in use in both Australia and New Zealand for over a decade and since November 2008 has been referenced within the New Zealand compliance document C/AS1. The FBIM is also accepted by the NZFS as a suitable methodology to demonstrate the performance requirements of the NZBC that relate to fire brigade operations. This research presents a first attempt at the collection of FBIM data specific to the NZFS and presents validation and verification of this data and the FBIM methodology against real emergency incidents and the NZFS operating tactics. Whilst this research cannot comprehensively conclude that the FBIM is entirely validated against all conditions within the New Zealand fire environment, the FBIM has been shown to be appropriate for use and should be able to be applied with confidence within New Zealand.

The IFEG references the use of the FBIM to quantify fire service activities to allow a design to incorporate fire brigade intervention and is endorsed by both the DBH and IPENZ. With sufficient data to represent NZFS operations and procedures the FBIM should be an accepted tool to demonstrate the performance requirements of the NZBC that relate to fire-fighting operations.

CHAPTER 12. References

1. **Alexandrovski, A.** *Fire Brigade Intervention Model, is it used properly?* School of Engineering, University of Western Sydney. November 2006. A research paper presented to the School of Engineering University of Western Sydney in fulfilment of the requirements for the degree Master in Fire Safety Engineering.

2. **Marsden, J.** Building barriers. *Fire Risk Managment Journal.* pp. 51-54. June 2009.

3. **Office of the Deputy Prime Minister.** *Physiological Assessment of Firefighting, Search and Rescue in the Built Environment.* London: 2007.

4. **British Standards Institution.** *PD 7974-5 Application of fire safety engineering principles to the design of buildings.* London: 2003.

5. **Australasian Fire Authorities Council.** *Fire Brigade Intervention Model.* Melbourne: 2004. Vol. 2.2.

6. **Department of Building and Housing.** *Acceptable Solution, Approved Documents for New Zealand Building Code Fire Safety Clauses C1, C2, C3, C4, Incorporating Amendments up to and including Amendment 7.* November. Wellington: 2008.

7. **Brown, N.** *Is rescue from a burning building about to become a thing of the past?* Fire Australia*.* Victoria: Winter 2008. pp. 20-21.

8. **Young, S A.** *AFAC FBIM Computer Program User Manual.* Melbourne: Australasian Fire and Emergencies Services Authorities Council, 2004. Vols. 1,3.

9. *Post-War Building Studies No. 29. Fire Grading of Buildings Part II. Fire Fighting Equipment.* London: Her Majesty's Stationery Office, 1952.

10. **Standards Association of New Zealand.** *NZS1900*: Chapter 5: Model Building Bylaw, Fire Resisting Construction and Means of Egress (including up to Amendment 2). Wellington: 1988.

11. **Department of Building and Housing.** About the Building Code. *Department of Building and Housing.* [Online] http://www.dbh.govt.nz/bcr-about-the-building-code [Cited: 05 01 2010].

12. **Building Industry Authority.** Protection of fire fighters in the alteration of a school building. *Determination 2001/5.* Wellington: 2001.

13. *Post-War Building Studies No. 20. Fire Grading of Buildings Part I. General principles and Structural Precautions.* London: Her Majesty's Stationery Office, 1952. Sections 109-112.

14. **Australian Building Codes Board.** *International Fire Engineering Guidelines.* Canberra: 2005.

15. **Department of Building and Housing.** Alternative solutions. *Department of Building and Housing.* [Online] http://www.building.dbh.govt.nz/blc-alternative-solutions [Cited: 30 01 2010].

16. **Department of Building and Housing.** BC Update: No.17 - Release of the International Fire Engineering Guidelines. *Department of Building and Housing.* [Online] http://www.dbh.govt.nz/bcupdate-article-17 [Cited: 03 04 2010].

17. **Institution of Professional Engineers New Zealand.** *Hot Topics. Fire Engineering Advisory Taskforce. Report and Recommendations.* Wellington: Institution of Professional Engineers New Zealand, 2007.

18. **Building Industry Authority.** *Determination 2001/5*: Protection of fire fighters in the alteration of a school building. Wellington: 2001.

19. **Department of Building and Housing.** *Determination 2009/100*: Refusal of an amendment to the fire engineering design forming part of a building consent for a multi-storey office building. Wellington: 2009.

20. **Merry, A and Spearpoint, M.** *The Building Act of 2004 and the New Zealand Fire Service.* Society of Fire Protection Engineers, SFPE International Conference on Performance-Based Codes and Fire Safety Design Methods. April 16-18. pp. 47-58. Auckland. 2008.

21. **Department of Building and Housing.** *Framework for Demonstrating Fire Safety*. Wellington: 2009.

22. **Hughes-Brown, B.** *Alternative Building Solutions and Real Building Fires.* University of Western Sydney, 2008. Built Environment Research Project.

23. **Department of Building and Housing.** *2005/109: Single means of escape from a high-rise apartment building*. Wellington: 2005.

24. **Warrington Fire Research.** *Technical Audit of the New Zealand Fire Service Design Review Unit*. Melbourne: Warrington Fire Research Australia, 2006.

25. **British Standards Institution.** *BS 9999: Code of practice for fire safety in the design, management and use of buildings*. London: British Standards Institution, 2008.

26. **Richards, P and Chuo, T.** *Case Study 01.* Society of Fire Protection Engineers, SFPE International Conference on Performance-Based Codes and Fire Safety Design Methods. April 16-18. Auckland. 2008.

27. **Cashin, B.** *Deconstructing the Building Code.* Wellington: Brookers Ltd, 2005.

28. **New Zealand Fire Service.** *Inquiry into the Explosion and Fire at Icepak Coolstores, Tamahere, on 5 April 2008 .* Wellington: New Zealand Fire Service Commission, 2008 . Incident Number F128045.

29. *Fire safety engineering – Part 1: Application of fire performance concepts to design objectives.* International Standards Organisation, 1999. ISO/TR 13387-1.

30. *Fire-safety engineering – Technical information on methods for evaluating behaviour and movement of people.* Switzerland: International Standards Organisation. ISO/TR 16738.

31. **International Code Council.** *Performance Code for Building and Facilities.* Country Club Hills, Illinois: International Code Council. 2009.

32. **International Code Council.** *International Fire Code.* Country Club Hills, Illinois: International Code Council. 2009.

33. **Australian Building Codes Board.** *Building Code of Australia.* Canberra: 2009.

34. **Australian Building Codes Board.** *The Guide to the Building Code of Australia.* Canberra: Australian Building Codes Board, 2009.

35. **Meacham, B.** *A Risk-Informed Performance-Based Approach to Building regulation.* Society of Fire Protection Engineers, SFPE International Conference on Performance-Based Codes and Fire Safety Design Methods. April 16-18. pp. 3-14. Auckland. 2008.

36. **Department for Communities and Local Government.** *Approved Document B (Fire safety) - Buildings other than dwellinghouses*. London: 2006. Vol. 2.

37. **Communities and Local Government.** Fire safety law and guidance documents for business. *Communities and Local Government website.* [Online] http://www.communities.gov.uk/fire/firesafety/firesafetylaw/ [Cited: 31 03 2010].

38. **British Standards Institution.** *BS 7974 Application of fire safety engineering principles to the design of buildings - Code of practice.* London: 2001.

39. **National Fire Protection Association.** *NFPA 5000 Building Construction and Safety Code.* Quincy: 2009.

40. **National Research Council Canada .** Fire Risk Assessment for Residential and Office Buildings - FiRECAM . *National Research Council Canada.* [Online] 04 04 2010. http://www.nrc-cnrc.gc.ca/eng/projects/irc/residential-protection.html [Cited: 05 04 2010].

41. **Benichou, N, Kashef, A and Hadjisophocleous, G.** *Fire Department Response Model (FDRM) and Fire Department Effectiveness Model (FDEM) Theory Report.* Fire Risk Management Program Institute for Research in Construction. National Research Council Canada, 2002. Internal Report No. 842.

42. **Yung, D T, Hadjisophocleous, G V and Yager, B L.** *Case study: The use of FiRECAM to identify cost-effective fire safety design options for a large 40-storey office building.* Pacific Rim Conference and 2nd International Conference on Performance Based Codes and Fire Safety Design Methods. pp. 441-452. NRCC-42040. Maui. 1998.

43. **Tillander, K.** *Utilisation of statistics to assess fire risks in buildings.* VTT Technical Research Centre. Helsinki: 2004.

44. **Tómasson, B, et al.** *The Influence of Fire Department Intervention for the Fire Safety of High-rise Buildings.* Society of Fire Protection Engineers, SFPE International Conference on Performance-Based Codes and Fire Safety Design Methods. April 16-18. pp. 205-216. Auckland. 2008.

45. **Tomasson, B, et al.** [ed.] B Karlsson. *A Probabilistic Risk Analysis Methodology for High-Rise Buildings Taking into Account Fire Department Intervention Time.* International Association for Fire Safety Science. Fire Safety Science – Proceedings of the Ninth International Symposium. pp. 957-968. Karlsruhe: 2009. doi:10.3801/IAFSS.FSS.9-957.

46. Guidelines. *South Australian Metropolitan Fire Service.* [Online] Government of South Australia, 21 08 2009. http://www.samfs.sa.gov.au/site/community_safety/commercial/guidelines.jsp [Cited: 03 04 2010].

47. **New South Wales Fire Brigade.** Guidelines for built environment. *New South Wales Fire Brigades.* [Online] New South Wales Government, 02 03 2010. http://www.nswfb.nsw.gov.au/page.php?id=28 [Cited: 03 04 2010].

48. **Metropolitan Fire and Emergency Services Board.** Fire Safety Guidelines. *Metropolitan Fire and Emergency Services Board.* [Online] REACTIVE, 2009.

http://www.mfb.vic.gov.au/Community-Safety/Workplace/Fire-Safety-Guidelines.html [Cited: 03 04 2010].

49. **Metropolitan Fire and Emergency Services Board.** *Performance Based Designs Fire Brigade Requirements,* 5. Victoria: 2004. Advisory No. B 6000/14.

50. **Metropolitan Fire and Emergency Services Board.** *Guideline No: GL-17 Fire Brigade Intervention Model (FBIM).* Victoria: 2005.

51. **Queensland Fire and Rescue Service.** *Policy on Fire Engineered Alternative Solutions*. Queensland Government. Queensland. 2006.

52. **Marchant, R, Kurban, N and Wise, S.** *Development and Application of the Fire Brigade Intervention Model.* 1st International Conference on Fire Service Deployment Analysis. Indianapolis, Indiana. 1999.

53. **VectorCommand Ltd.** *Tactical Command Trainer*. [Online] 2010. http://www.emergencycommandsystem.com/products/tactical-command-trainer/ [Cited: 03 04 2010].

54. **British Standards Institution.** *BS 6391 Specification for non-percolating layflat delivery hoses and hose assemblies for fire fighting purposes.* London: 2009.

55. **Palisade Corporation.** *@Risk The Decision Tools Suite version 5.5.0*, Industrial Edition. Newfield, NY: Palisade Corporation, 2009.

56. **O'Brien, T.** Private communication. 2010.

57. **Houston, B.** Private communication. 2010.

58. **Mak, C.** Private communication. 2010.

59. *Fire Detection and Alarm Systems in Buildings*. Wellington: Standards New Zealand, 2003. NZS 4512.

60. **New Zealand Fire Service.** *Station Management System Incident Data.* Wellington: 2008 – 2009.

61. **Commission on Fire Accreditation International, Inc.** *Creating and Evaluating Standards of Response Coverage for Fire Departments.* Chantilly, VA: Public Entity Risk Institute, 2003. 4th edition.

62. **Office of the Fire Marshal Ontario.** Fire Station Location. *Office of the Fire Marshal Ontario.* [Online] Queen's Printer for Ontario, 2009, 14 12 2009. http://www.ofm.gov.on.ca/english/FireProtection/munguide/04-87-13.asp. PFSG 04-87-13 [Cited: 16 12 2009].

63. **Kolesar, P and Walker, W.** *Measuring the Travel Characteristics of New York City's Fire Companies.* New York: New York City RAND Institute, 1979. R-1449-NYC.

64. **National Fire Protection Association.** *NFPA 1710 Standard for the Organization and Deployment of Fire Suppression Operations Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments.* Quincy: 2010.

65. **Averill, J D, et al.** *NIST Technical Note 1661Report on Residential Fireground Field Experiments U.S. Department of Commerce National Institute of Standards and Technology.* National Institute of Standards and Technology. U.S. Department of Commerce, 2010.

66. The Fire Cover Review 2000. *Communities and Local Government.* [Online] 2000. http://www.communities.gov.uk/archived/general-content/fire/firecover/ [Cited: 16 12 2009].

67. **Greenstreet Berman Ltd.** *Review of Fire and Rescue Service response times.* London: Communities and Local Government Publications, 2009. Fire Research Series 1/2009.

68. **Caliper Corporation .** TransCAD Overview. *TransCAD transportation planning software.* [Online] 2009. http://www.caliper.com/tcovu.htm [Cited: 16 12 2009].

69. **Yung, D.** *Principles of Fire Risk Assessment in Buildings.* Chichester: Wiley, 2008.

70. **Google.** GoogleMaps. [Online]. http://maps.google.co.nz/maps?ct=reset [Cited: 17 12 2009].

71. **Jones, W and Bukowski, R.** *Critical information for first responders, whenever and wherever it is needed.* Edinburgh: Interscience Communications Ltd, International Interflam Conference, 9th Proceedings. Vol. 2. September 17-19. 2001.

72. **Massingberd-Mundy, P.** *FireGrid – An integrated emergency response system.* Duisburg: 14th International Conference on Automatic Fire Detection. September 8-10. 2009.

73. **Strakosch, G R.** *The Vertical Transportation Handbook.* Third ed. New York: John Wiley & Sons, Inc., 1998.

74. **Klem, J T.** *Preliminary Investigation Report Prudential Building Fire, Boston MA, January 2, 1986*. Quincy, MA: National Fire Protection Association, 1986.

75. **Lawson, J and Vettori, R.** *Reports of the Federal Building and Fire Investigation of the World Trade Center Disaster NIST NCSTAR 1-8: The Emergency Response Operations.* Building and Fire Research Laboratory. Washington: National Institute of Standards and Technology, 2005. NIST NCSTAR 1-8.

76. **Mississauga Fire And Emergency Services.** *Vertical response time trials August 5, 6, 7*. Ontario: 2009.

77. **Office of the Fire Marshal Ontario.** *Assessing vertical response times.* October/November 2009, Ontario: 2009, The Ontario Fire Service Messenger, p. 23. PM40005428/R1001817.

78. **Kuligowski, E D and Bukowski, R W.** *Design of Occupant Egress Systems for Tall Buildings.* 2004. CIB World Building Congress. Toronto: May 2-7 pp. 1-10.

79. **Federal Emergency Management Agency.** *U.S. Fire Administration Firefighter Fatalities in the United States in 2008*. [Online]. U.S. Department of Homeland Security, September 2009. http://www.usfa.dhs.gov/downloads/pdf/publications/ff_fat08.pdf. [Cited: 05 04 2010].

80. **New Zealand Fire Service.** Firefighting Water Supplies Code of Practice. *SNZ PAS 4509:2008.* Wellington: Standards New Zealand, Publicly Available Specification, 2008.

81. **Professional Development Unit.** *Recruit Course Student Note: Breathing Apparatus.* New Zealand Fire Service, 2005.

82. **Beard, A and Carvel, R.** *Handbook of tunnel fire safety.* Thomas Telford, London: 2005.

83. **Australasian Fire and Emergency Services Authorities Council.** Code Of Practice Aerial Appliance - Safe Use and Minimum Maintenance. Melbourne: 2003.

84. **Wright, M.** *Prescriptive versus Alternative Solutions.* Fire Australia 2009 Conference and Exhibition, October 28 -29, Hobart: 2009.

85. **Wade, C A.** BRANZFIRE Technical Reference Guide. *BRANZ Study Report No 92.* Judgeford: Building Research Association of New Zealand, 2004 (revised).

86. *Automatic Fire Sprinkler Systems*. Wellington: Standards New Zealand, 2007. NZS 4541.

Appendix A

Gazette Notice

Gazette Notice

This Gazette notice dated 24 March 2005 requires the following type of building consent applications to be sent to the NZFSC:

1. An application for a building consent that relates to building work to be carried out in respect of any type of building or part of a building described in section 21A of the Fire Service Act 1975 regardless of whether the building or part of the building is sprinkler protected.

2. For the purpose of clause 1 an application for a building consent for building work means an application—

   a) where compliance with clauses C1-4, D1, F6 or F8 of the Building Code will be established other than by compliance with the provisions of an applicable compliance document; or
   b) that involves a modification or waiver of clauses C1-4, D1, F6 or F8 of the Building Code, under section 67 of the Building Act 2004; or
   c) that involves an alteration, change in use or subdivision and affects the fire safety systems, including any building work on a specified system relating to fire safety, except where the effect on the fire safety system is minor.

3. Clause 1 does not apply to an application for a building consent for building work to be carried out in respect of:

   a) single household units;
   b) buildings in which every fire-cell is a household unit separated vertically from the other fire-cells and each fire-cell has independent and direct egress to a safe place outside the building;
   c) an internal fit-out, unless the fit-out relates to a change of use under clause 2(c);
   d) outbuildings or ancillary buildings.”

Appendix B

Part A0 of the Guide to the BCA

PART A0 APPLICATION

A0.8 Alternative Solutions

Intent

To state the process for proving that an Alternative Solution complies with the BCA.

A building proponent may decide to meet the Performance Requirements via a route which is not included in a Deemed-to-Satisfy Provision. This is referred to as an Alternative Solution.

Options are available for people wishing to use Alternative Solutions to meet a Performance Requirement.

For example: building proponents who wish to know what has to be done to satisfy the fire-safety Performance Requirements of a particular building can either follow the Deemed-to-Satisfy Provisions or adhere to one of the proven Alternative Solutions. For Alternative Solutions they might, for example, refer to:

- the International Fire Engineering Guidelines (Edition 2005) published by the Australian Building Codes Board; or
- the Fire Brigade Intervention Model (FBIM) as developed by the Australasian Fire Authorities Council (AFAC) to assist with determining fire brigade response times.

Such alternative guidelines may be endorsed by the Board as appropriate and safe yardsticks.

They are examples of Alternative Solutions at work and demonstrate the flexibility of the BCA.

When using an Alternative Solution, it is important to ensure that it complies with all parts of the BCA as required by A0.10.

Appendix C

Australian State Legislation

South Australian legislation

The South Australian Fire and Emergency Services Act 2005

Division 2—Functions and powers

26—Functions and powers

(1) MFS has the following functions:

(a) to provide services with a view to preventing the outbreak of fires, or reducing the impact of fires, in any fire district;

(b) to provide efficient and responsive services in any fire district for the purpose of fighting fires, dealing with other emergencies or undertaking any rescue;

(c) to protect life, property and environmental assets from fire or other emergencies in any fire district;

(d) to develop and maintain plans to cope with the effects of fires or emergencies in any fire district;

(e) to provide services or support to assist with recovery in the event of a fire or other emergency in a fire district;

(f) to perform any other function assigned to MFS by or under this or any other Act.

The South Australia Development Regulations 2008

28—Special provisions—referrals

(3) If a relevant authority, in assessing an application for building rules consent, considers that—

(a) a proposed alternative solution within the meaning of the Building Code requires assessment against a performance requirement of the Building Code which provides for fire fighting operations of a fire authority; or

(b) the proposed development is at variance with a performance requirement of the Building Code which provides for fire fighting operations of a fire authority; or

(c) special problems for fire fighting could arise due to hazardous conditions of a kind described in Section E of the Building Code, then the relevant authority must refer the application to the relevant fire authority for comment and report unless the fire authority indicates to the relevant authority that a referral is not required.

(4) If a report is not received from the fire authority on a referral under subregulation (3) within 20 business days, the relevant authority may presume that the fire authority does not desire to make a report.

(5) The relevant authority must have regard to any report received from a fire authority under this regulation.

(6) A relevant authority must provide to the Building Rules Assessment Commission a copy of any report received from a fire authority under subregulation (3) that relates to an application that is referred to the Building Rules Assessment Commission under the Act.

83—Certificates of occupancy

(4) If—

(a) a building is—

(i) to be equipped with a booster assembly for use by a fire authority; or

(ii) to have installed a fire alarm that transmits a signal to a fire station or to a monitoring service approved by the relevant authority; and

(b) facilities for fire detection, fire fighting or the control of smoke must be installed in the building pursuant to an approval under the Act, the council must not grant a certificate of occupancy unless or until it has sought a report from the fire authority as to whether those facilities have been installed and operate satisfactorily.

(5) If a report is not received from the fire authority within 15 business days, the council may presume that the fire authority does not desire to make a report.

(6) The council must have regard to any report received from a fire authority under subregulation (4) before it issues a certificate of occupancy.

New South Wales Legislation

Fire Services Act 1989

Part 2 – Provision of fire services etc

6 Duty to deal with fires and hazardous material incidents

(1) It is the duty of the Commissioner to take all practicable measures for preventing and extinguishing fires and protecting and saving life and property in case of fire in any fire district.

(2) It is the duty of the Commissioner to take all practicable measures:

(a) for protecting and saving life and property endangered by hazardous material incidents, and

(b) for confining or ending such an incident, and

(c) for rendering the site of such an incident safe.

7 General authority to protect persons and property

(1) The Commissioner is authorised to take measures anywhere in the State for protecting persons from injury or death and property from damage, whether or not fire or a hazardous material incident is involved.

(2) In the case of fire, it does not matter whether or not the persons are, or the property is, within a fire district.

Part 3 – Fighting and preventing fires and dealing with hazardous material incidents

Division 1 – Powers at fires and hazardous material incidents

11 Brigades to proceed with speed to suspected fires or hazardous material incidents

(1) When there is an alarm of fire, a fire service must, despite anything to the contrary in any Act, proceed with all speed to the fire and try by all possible means to extinguish it and save any lives and property that are in danger.

(2) When there is a report of a hazardous material incident, a fire service must,

despite anything to the contrary in any Act:

(a) proceed with all speed to the site of the incident, and

(b) try by all possible means to render the site of the incident safe and save any lives and property that are in danger.

The Environmental Planning and Assessment (EP&A) Regulation 2000

144 Referral of certain plans and specifications to New South Wales fire services

(cf clause 79F of EP&A; Regulation 1994)

(1) This clause applies to:

(a) a class 9a building that is proposed to have a total floor area of 2,000 square metres or more, or

(b) a building (other than a class 9a building) that is proposed to have:

(i) a fire compartment with a total floor area of more than 2,000 square metres, or

(ii) a total floor area of more than 6,000 square metres,

where:

(c) the building is the subject of an application for erection, rebuilding, alteration, enlargement or extension, and

(d) the plans and specifications for the erection, rebuilding, alteration, enlargement or extension provide for an alternative solution to meet the performance requirements contained in any one or more of the Category 2 fire safety provisions.

(2) As soon as practicable after receiving an application for a construction certificate for a building to which this clause applies, the certifying authority must forward to the Fire Commissioner:

(a) a copy of the application, and

(b) a copy of the plans and specifications for the building, and

(c) details of the performance requirements that the alternative solution is intended to meet, and

(d) details of the assessment methods to be used to establish compliance with those performance requirements, which may be delivered by hand, forwarded by post or transmitted electronically, but may not be sent by facsimile transmission.

(3) The Fire Commissioner must furnish the certifying authority with an initial fire safety report for the building.

(4) An initial fire safety report may recommend conditions to be imposed on the erection, rebuilding, alteration, enlargement or extension of the building to which the report relates.

(5) The certifying authority must not issue a construction certificate for a building to which this clause applies unless:

(a) it has received an initial fire safety report for the building and has taken the report into consideration, or

(b) at least 23 days have elapsed since the plans and specifications were forwarded to the Fire Commissioner but no such report has been received by the certifying authority.

(6) If the certifying authority does not adopt any recommendation in an initial fire safety report:

(a) because the report had not been received when the construction certificate was issued, or

(b) because the certifying authority does not agree with the recommendation, the certifying authority must cause written notice to be given to the Fire Commissioner of the fact that it has not adopted the recommendation and of the reasons why it has not adopted the recommendation.

(7) If the certifying authority adopts any condition recommended by an initial fire safety report:

(a) it must ensure that the terms of the recommended condition have been included in the plans and specifications for the building work, in the case of a condition whose terms are capable of being so included, or

(b) it must attach to the construction certificate a condition in the same terms as those of the recommended condition, in the case of a condition whose terms are not capable of being so included.

(8) Compliance with the requirement that the terms of a recommended condition be included in the plans and specifications for building work is sufficiently complied with:

(a) if the plans and specifications are redrawn so as to accord with those terms, or

(b) if those terms are included by way of an annotation (whether by way of insertion, deletion or alteration) marked on the relevant part of those plans and specifications.

(9) In this clause:**"initial fire safety report"** means a written report specifying whether or not the Fire Commissioner is satisfied, on the basis of the documents referred to in subclause (2):

(a) that the alternative solution will meet such of the performance requirements as it is intended to meet, and

(b) that the fire hydrants in the proposed fire hydrant system will be accessible for use by New South Wales fire services, and

(c) that the couplings in the system will be compatible with those of the fire appliances and equipment used by New South Wales fire services.

144A Compliance certificate required for certain fire safety aspects of building work

(1) A certifying authority must not issue a construction certificate for building work that involves an alternative solution under the Building Code of Australia in respect of a fire safety requirement unless the certifying authority has obtained or been provided with a compliance certificate referred to in section 109C (1) (a) (v) of the Act that:

(a) was issued by a person holding Category C10 accreditation under the Building Professionals Act 2005, and

(b) certifies that the alternative solution complies with the relevant performance requirements of the Building Code of Australia.

(2) Until 28 February 2010, this clause applies only to building work in respect of:

(a) a class 9a building, as defined in the Building Code of Australia, that is proposed to have a total floor area of 2,000 square metres, and

(b) any building (other than a class 9a building) that is proposed to have:

(i) a fire compartment, as defined in the Building Code of Australia, with a total floor area of 2,000 square metres, or

(ii) a total floor area of more than 6,000 square metres, that involves an alternative solution under the Building Code of Australia in respect of the requirements set out in EP1.4, EP2.1, EP2.2, DP4 and DP5 in Volume 1 of that Code.

(3) From 1 March 2010, this clause applies to all building work that involves an alternative solution under the Building Code of Australia in respect of a fire safety requirement.

152 Reports of Fire Commissioner: section 109H

(cf clause 79M of EP&A; Regulation 1994)

(1) This clause applies to a building to which clause 144 applies.

(2) Unless it has already refused such an application, a certifying authority must request the Fire Commissioner to furnish it with a final fire safety report for a building as soon as practicable after receiving an application for an occupation certificate for the building.

(3) If it refuses the application after making such a request but before receiving a final fire safety report, the certifying authority must cause notice of the refusal to be given to the Fire Commissioner.

(4) Unless it has received a notice referred to in subclause (3), the Fire Commissioner must furnish the certifying authority with a final fire safety report for the building within 7 days after receiving a request for the report.

(5) The certifying authority must not issue an occupation certificate for the building unless it has taken into consideration any final fire safety report for the building that has been furnished to it within the 7-day period.

(6) In this clause:**"final fire safety report"** for a building means a written report

specifying whether or not the Fire Commissioner is satisfied:

(a) that the building complies with the Category 2 fire safety provisions, and

(b) that the fire hydrants in the fire hydrant system will be accessible for use by New South Wales fire services, and

(c) that the couplings in the fire hydrant system will be compatible with those of the fire appliances and equipment used by New South Wales fire services.

<u>Victorian legislation</u>

The Metropolitan fire services Act 1958

SECT 32B. Action on alarm of fire

(1) For the purposes of this section, the Chief Officer is responsible for the control and direction of all members of units in the metropolitan district.

(2) On an alarm of fire being received by a unit, those members of the unit specified by the Chief Officer must, with the appliances and equipment specified by the Chief Officer, proceed with all practical speed to the scene of the alarm of fire.

(3) At the scene of an alarm of fire the senior member of the operational staff-

(a) shall endeavour by all practical means to have any fire suppressed and any person or property in jeopardy saved;

(b) shall have the control and direction of any unit present and of all persons assisting any unit or units at the scene;

(c) may, for the purposes of dealing with any alarm of fire, cause-

(i) any land building structure vessel or vehicle to be entered upon or into (if necessary by force), taken possession of, shored up, pulled down, otherwise destroyed or removed;

(ii) any vehicle or equipment to be taken through upon or into any land building structure vessel or vehicle;

(iii) water to be shut off from any main pipe or other source of supply in order to obtain a greater pressure or supply of water; and

(iv) any road waterway railway or tramway to be closed to traffic or any main pipeline conduit or conductor of gas electricity oil or any source of power fuel or energy to be shut off;

(d) may order to withdraw any persons who interfere by their presence or otherwise with the operation of the unit or units, and cause to be removed any persons who fail or refuse to comply with any such order to withdraw; and

(e) may take such other measures as appear necessary for the protection of life and property.

Country Fire Authority Act 1958

20 General duty of Authority

The duty of taking superintending and enforcing all necessary steps for the prevention and suppression of fires and for the protection of life and property in case of fire and the general control of all stations and of all brigades and of all groups of brigades shall, subject to the provisions of this Act, so far as relates to the country area of Victoria be vested in the Authority.

Victorian Building Regulations 2006

PART 3—BUILDING PERMITS

309 Requirements for permits involving fire safety matters

(1) The report and consent of the chief officer must be obtained to an application for a building permit which involves any of the following fire safety matters if those matters do not meet the deemed to

satisfy provisions of the BCA—

(a) fire hydrants;

(b) fire hose reels;

(c) fire control centres or fire control rooms;

(d) fire precautions during construction;

(e) fire mains;

(f) control valves;

(g) booster assemblies;

(h) emergency vehicle access;

(i) fire indicator panels;

(j) proscenium curtain drencher systems;

(k) Fire Services controls in passenger lift cars.

(2) In a report under subregulation (1), the chief officer may consent to a variation of the requirements of the BCA if the chief officer is satisfied that a satisfactory degree of fire safety is achieved.

(3) When a building permit is issued which involves the installation of fire sprinklers and the installation does not meet the deemed-to-satisfy provisions of the BCA the relevant building surveyor must forward details of the installation to the chief officer.

PART 10—OCCUPANCY PERMITS AND CERTIFICATES OF FINAL INSPECTION

1003 Reporting authorities for occupancy permit

(1) The report and consent of the chief officer must be obtained in respect of an application for an occupancy permit—

(a) if he or she was a reporting authority in respect of the application for the building permit which required the issue of the occupancy permit; or

(b) in relation to the transmission signal of alarms required, under these Regulations or any previous corresponding regulations, to be connected to a fire station or other approved monitoring service.

1015 Building surveyor to notify chief officer of issue of certificates of final inspection

(1) If a certificate of final inspection is issued for building work in respect of which there is a requirement under these Regulations or any previous corresponding regulations that the transmission signal of an alarm be connected to a fire station or other approved monitoring service, the relevant building surveyor must notify the chief officer within 10 days after the issue of the certificate that—

(a) the certificate has been issued; and

(b) the required connection has been made.

(2) If a certificate of final inspection is issued for building work for which an occupancy permit is not required and the chief officer was a reporting authority in respect of the application for the relevant building permit, the relevant building surveyor must notify the chief officer within

10 days after the issue of the certificate that the certificate has been issued.

Queensland

Fire and Rescue Service Act 1990

8B Functions of service

The functions of the service are—

(a) to protect persons, property and the environment from fire and hazardous materials emergencies; and

(b) to protect persons trapped in a vehicle or building or otherwise endangered, to the extent that the service's personnel and equipment can reasonably be deployed or used for the purpose; and

(c) to provide an advisory service, and undertake other measures, to promote—

(i) fire prevention and fire control; and

(ii) safety and other procedures if a fire or hazardous materials emergency happens; and

(d) to cooperate with any entity that provides an emergency service; and

(e) to perform other functions given to the service under this Act or another Act; and

(f) to perform functions incidental to its other functions; and

(g) to identify and market products and services incidental to its functions.

Schedule 2 Referral agencies and their jurisdiction

Application involving	Referral agency and type	Referral jurisdiction
Fire safety system—generally		
1 A fire safety system for a building or structure, other than a temporary or special structure, if the building work— (a) requires special fire services mentioned in schedule 2A, part 1; or (b) includes an alternative solution[a] assessed against the performance requirements of the Building Code of Australia, Volume 1, or the Queensland Development Code, part 14.1, for the fire safety system	Queensland Fire and Rescue Service—as an advice agency	For the special fire services mentioned in schedule 2A, part 1—the matters mentioned in schedule 2A, part 2 For item 1(b)—the *Building Act 1975*, chapters 3 and 4

Application involving	Referral agency and type	Referral jurisdiction
Fire safety system—budget accommodation buildings		
2 A fire safety system for a budget accommodation building if the work involves a solution— (a) assessed against— (i) the performance criteria stated in the Queensland Development Code, part 14; or (ii) the performance requirements of the Building Code of Australia, volumes 1 and 2, for the fire safety system; and (b) that includes fire safety management procedures as a condition of the use and occupation of the building	Queensland Fire and Rescue Service—as an advice agency	The fire safety management procedures under the *Fire and Rescue Service Act 1990*
Residential care buildings		
2A A residential care building under the Queensland Development Code, part 14.1	Queensland Fire and Rescue Service—as an advice agency	For item A2 of the acceptable solutions stated in the Queensland Development Code, part 14.1—compliance with the Queensland Development Code, part 14.1, schedule 2 For item P2 of the performance criteria stated in the Queensland Development Code, part 14.1—the fire and evacuation plan for the building under the *Fire and Rescue Service Act 1990*

Appendix D

MFB FBIM Guideline

Metropolitan Fire & Emergency Services Board *Community Safety Directorate* **GUIDELINE** **Fire Brigade Intervention Model (FBIM)** ***General Provisions***			*Guideline No:* ***GL-17*** *Prepared By:* MFB Community Safety Advisory Group *Authorised By:* ACFO Greg Bawden
First Issued: *24 June 2003*	*Version No: 2* *15 September 2005*	*Reviewed:* *10 October 2006*	*Page 1 of 4*

1. Purpose

To provide advice relative to when the Fire Brigade Intervention Model (FBIM) should be carried out and the information required to undertake the model.

2. BCA Requirements

In 1996, a performance based building code[1] was introduced in Australia. To ensure that the Fire Brigades' functional role was maintained in the building code, a method of quantifying Fire Brigade roles was required. In response to this issue, the Australasian Fire Authorities Council (AFAC) formed a Performance Based Fire Engineering Committee. This committee developed a model that determines the time taken by a Fire Brigade to undertake its activities at a fire scene.

In addition to the objectives and functional statements of the BCA, the following performance requirements are specific to Fire Brigade Intervention.

- CP1 Structural stability during a fire.
- CP2 Avoiding spread of fire.
- CP9 Access provided to and around a building for fire brigade vehicles and personnel.
- DP5 Fire isolated exits.
- EP1.3 Fire hydrants.
- EP1.5 Fire fighting equipment in a building under construction.
- EP1.6 Facilities to co-ordinate fire brigade intervention.
- EP2.2 Evacuation time of occupants.
- EP3.2 Emergency lifts.
- GP4.4 Fire safety system in an alpine area.

3. What Is FBIM and When Is It Required?

The "Fire Brigade Intervention Model"[2] is an event-based methodology, which quantifies Fire Brigade activities employed during a fire from time of notification through to control and extinguishment. It has been primarily developed for use in fire engineering design in a performance based regulatory environment so that the functional role of a Fire Brigade can be effectively incorporated into the building design process. It establishes a structured framework necessary to both determine and measure Fire Brigade activities on a time-line basis. It interacts with the outputs of other sub-systems which model such events as fire growth, smoke spread, fire spread, detection and suppression as well as occupant avoidance. The model has been developed for use on specific site characteristics and is applicable to most fire scenarios. As the expertise of the local Fire Brigade will be incorporated in the input parameters, it is valid for most brigade types, crew sizes and resource limitations.

[1] Australian Building Codes Board (1996) – The Building Code of Australia, Vol. 1, Class 2 to Class 9 Buildings – CCH Australia Limited

[2] Australasian Fire Authorities Council, 2004 – Fire Brigade Intervention Model – Version 2.2 – October 2004

Appendix E

Incident Attendance

Summary of incident attendance

Table 55 Summary of incident attendance

Fire region	Shift	Incidents attended	Transcad distances	Travel distance from Google	Difference %	Mean travel speed km/h	Description of incident
Auckland	night	0					~
Auckland	night	1					PFA - FA
Auckland	night	0					~
Auckland	night	2	12.6	84.6	14.9	67.5	MVA - 4 persons trapped
			2.4	56.7	4.2	47.0	PFA - FA
Auckland	night	0					~
Auckland	night	0					~
Wellington	night	3	2.7	71.3	3.8	29.7	PFA - FA
			1.5	50.0	3.0	31.0	PFA - FA
			0.4	66.7	0.6	20.0	PFA - FA
Auckland	night	4	0.3	80.6	0.4	19.3	Theatrical smoke nuisance alarm
			1.7	70.0	2.4	42.9	PFA - FA
			3.0	67.5	4.4	44.8	house fire
			1.5	1.7	88.2	21.0	PFA - FA
Auckland	night	3	0.9	69.6	1.3	40.0	Rubbish bin fire
			2.4	67.6	3.5	45.2	MVA - 1 deceased
			1.5	69.5	2.2	41.6	bin fire
Wellington	night	2	2.1	82.1	2.6	29.6	PFA - FA cooking
			1.3	70.7	1.8	33.8	PFA - FA

Appendix G

FBIM Data Collection Sheets

Fire Brigade Intervention Model Exercises

Introduction

The Fire Brigade Intervention Model (FBIM) developed by the Australasian Fire and Emergency Services Authorities Council (AFAC) provides a methodology to assess fire service intervention and the impact of fire service operations on building designs. The FBIM is aimed at addressing the issues applicable to building design as they relate to fire, therefore those activities a Fire Service undertakes to achieve the aims of life safety and protection to and from adjoining property are relevant. Of the upmost importance is that whilst working towards achieving these goals, **fire fighter life safety is addressed**.

The FBIM has been in existence for over a decade and is used regularly throughout Australia and to a lesser extent in New Zealand. Since November 2008 the FBIM has been referenced within the Building Code Acceptable Solutions, C/AS1 and is accepted by the New Zealand Fire Service as an acceptable methodology to demonstrate the performance requirements of the New Zealand Building Code relating to Fire Service operations. However, the FBIM only contains data from the various Australian Fire Brigades and contains no NZFS data reflecting NZFS operations. To ensure that the data being used within the model accurately represents current NZFS operational practises and the New Zealand environment the following exercises have been developed to collect the statistical data required to populate the FBIM with NZFS data and to validate the FBIM methodology against NZFS Standard Operational Procedures:

Exercise 1 - Hose operations
Exercise 2 - Hydrant riser operations
Exercise 3 - Taking Hose up Stairs
Exercise 4 - Personnel movement, including up stairs
Exercise 5 - Search and rescue
Exercise 6 - Aerial appliance set up
Exercise 7 - Obtaining water from non reticulated supply
Exercise 8 - Hazmat

These exercises have been developed to obtain specific statistical data, to ensure that necessary provisions are incorporated in building design for fire brigade operational tasks, and **to ensure fire fighter safety**. While the activities listed within the exercises may not exactly correspond to events on a fire ground, they have been designed for general coverage and maximum flexibility of data. It is acknowledged that on the fire ground, some activities may be undertaken simultaneously and timing of each individual activity becomes difficult. <u>For this reason the exercises have been developed so that each task is undertaken consecutively for timing purposes</u>.

No indication of the brigade (except brigade type i.e. Permanent/Volunteer) or station is required to be included on the activity time sheet. All data recorded will be anonymous and will only be used for statistical FBIM data collection.

The exercises should not be considered as a competitive assessment, but normal fire ground speed is required.

Typical resources required

- Type 1,2 or 3 appliance with officer and 3 fire-fighters
- Breathing apparatus for 2 fire fighters
- A wristwatch/stopwatch to record the time taken for each exercise in seconds
- A method of measuring the distances between the appliance and target (such as the standpipe). Hose can be used as a measuring aid to calculate distances.

The data is intended to be used for statistical purposes with distributions used for each activity rather than a single 'averaged' time or speed. For this reason the greater the amount of data collected the more accurate and reliable results will be produced. We therefore encourage these exercises to be used as many times as practicable for each brigade and under different conditions and circumstances. Different conditions including, distances and number of hoses used in each exercise as well as the terrain, time of day and weather conditions will increase the variability and relevance of the data collected to that found in real fire conditions.

Notes for the Officer in charge

It becomes very difficult to write down all the times if the whole drill is carried out as at a fire scene. So much happens at once. If attempting to work as at a fire scene, times for some activities will be missed whilst writing down the times of other activities. It is therefore necessary to break down the process into manageable steps.

It is important that the drill be carried out and should not be cancelled because of unforeseen difficulties which may be faced in conducting the drill. The officer should comment on any issue which caused a variation to the drill or affected recorded times. A timing sheet is provided with each exercise so that only the times and notes for each exercise need to be recorded. Please fill in the sheet and photocopy, fax or email this in to the following address:

Ed Claridge

Fire Engineering Unit

2 Poynton Terrace, Off Pitt Street
PO Box 68 042
Newton
Auckland

Phone 09 354 5103
Fax 09 302 5170
E-mail: Ed.Claridge@fire.org.nz

Exercise 1 Hose operations

All fire fighters to be dressed in full level 2 uniform. 1 fire fighter to establish a feed supply from a fire hydrant to a pump appliance, then 2 fire fighters in BA shall set up a low pressure delivery and discharge water. The officer-in-charge/observer will record times for each activity. All work to be carried out at normal fire ground speed and in accordance with NZFS standard operational procedures (SOP's).

Recommended resources

- Pump appliance with officer and 3 fire-fighters
- BA for 2 fire fighters
- A wristwatch/stopwatch to record the time taken for each exercise in seconds
- A method of measuring the distances between the appliance and target (such as the standpipe).

Method

Drill 1 **Connect and charge sufficient lengths of feeder hose between a fire appliance and the nearest hydrant at a measured distance from the inlet on the appliance**

Position the appliance, driver engage pump (if cab control), alight, withdraw all necessary equipment to connect to the hydrant (e.g. standpipe, plate lifter, hydrant bar, turn keys).

Prepare hydrant for connection (e.g. ship standpipe, remove cap, flush). If using coiled hose (please note) return for the lengths of coiled hose, connect hose and charge, return to appliance.

Drill 2 **2 Fire fighters at signal from officer, dismount with BA (or remove from locker and don). Lay and charge not less than two 25 m lengths of delivery hose between a fire appliance and branch operator a measured distance from the outlet on the appliance**

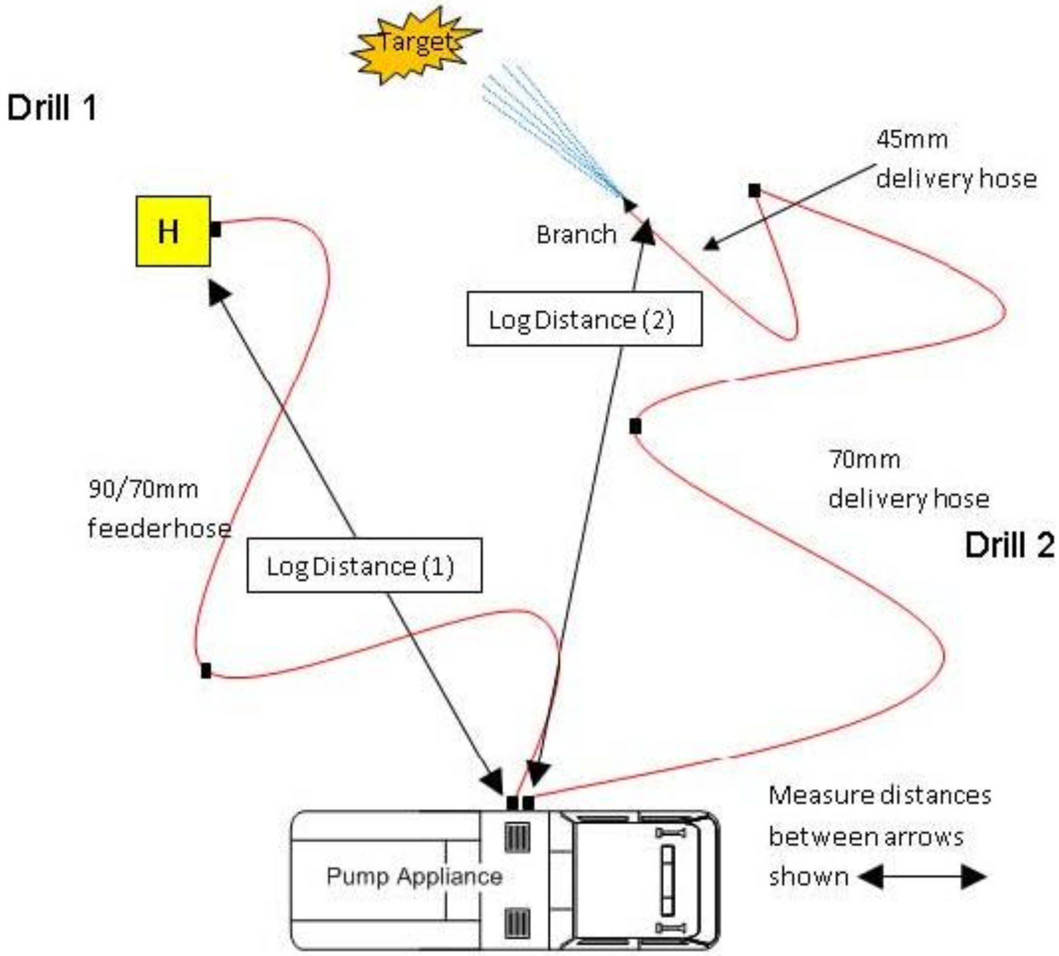
2 Fire fighters at signal from officer, dismount with BA donned (if not using seat mounted BA remove BA from locker and don), lodge BA tallies and complete BA control procedures at appliance, start BA at appliance or as a separate task before showing water.

Lay hose to designated operation point. Pump operator to charge lines so branch operator can flow water with appliance delivering at required operating pressure.

Note:

It is recognised that BA may not be donned and started at the fire appliance as this may occur once the fire fighters have laid out the delivery hose when simulating real incident conditions. Where BA is not donned and started at the appliance please ensure that the times indicated within the table reflect the correct order of tasks completed.

DIAGRAM OF DRILL



Drill 1 - Driver /Pump Operator only		Time Start	Time Finish	Time Taken	Comments
Time to engage pump, dismount, gather necessary equipment to prepare hydrant for flow					
Time to travel to hydrant					
Time to prepare hydrant and flush					
If using flaked hose.	Time to charge ___ (No.) of 30/25m lengths feed hose of diameter ___mm				
	Return time to appliance from hydrant				
If using coiled hose.	Return time to appliance from hydrant				
	Time to unpack, connect and charge ___ (No.) of 30/25m coiled lengths of diameter ___mm				
	Return time to appliance from hydrant				

Drill 2- 2 fire-fighters	Time Start	Time Finish	Time Taken	Comments
Time to dismount, remove, don BA and lodge tallies				
Time to unpack lay and connect ___(No.) of 25 m lengths of (coiled/flaked) hose of diameters ____mm				
Time taken to don face mask, test seals, start BA, and complete safety checks				
Time to bring delivery up to required pressure with hose stream operating				

Please indicate:

1	Horizontal distance from appliance outlet to branch operator position (m)	
2	Horizontal distance from appliance inlet to fire hydrant position (m)	
Brigade type		NZFS Permanent/ Volunteer/ Defence/ Rural

Exercise 2 Hydrant riser operations

This drill is ideally carried out at an industrial complex which has an external hydrant/booster connection and feed hydrants from a street main. Where only an internal hydrant riser system is located part 1 of this exercise can be used in isolation if charging and operating a hose line internally is not possible.

All fire fighters to be dressed in full level 2 uniform. One fire fighter to establish a single hose line feed/inlet from a fire hydrant to a pump appliance. 1 fire fighter to connect sufficient lengths of hose line from the appliance into the hydrant riser / booster inlets and charge the system. 2 fire fighters in BA will lay hose from the hydrant riser / booster outlets and discharge water at operational pressure. The officer-in-charge will record times for each activity.

Recommended resources

- Pump appliance with officer and 3 fire-fighters
- BA for 2 fire fighters
- recommended 5 lengths of hose (2 x 90mm, 2 x 70mm & 1 x 45mm)
- Equipment to connect to the hydrant used (e.g. for a below ground hydrant a standpipe will be necessary)
- An internal/external hydrant installation which incorporates an inlet assembly
- A stopwatch to record the time taken for each exercise in seconds
- A method of measuring the distances between the appliance and target (such as the standpipe).

Method

Drill 1 Water supply to the appliance and to the hydrant riser/booster inlets

- Connect and charge sufficient lengths of hose between a fire appliance and the nearest hydrant a measured distance from the inlet on the appliance
- Lay and charge sufficient lengths of delivery hose between a fire appliance and hydrant riser/booster inlets a measured distance from the outlet on the appliance.

As per SOP's, position a pump appliance with sufficient space to lay and charge hose lines to hydrant riser/booster inlet connections and obtain operational pressure at discharging outlet.

Driver engage pump (if cab control), alight, withdraw all necessary equipment to connect to the hydrant (e.g. standpipe, plate lifter, hydrant bar, turn keys), prepare hydrant for connection (e.g. ship standpipe, remove cap, flush). If using coiled hose (please note) return for the lengths of coiled hose, connect hose and charge, return to appliance.

Lay delivery hose to designated hydrant riser inlet/booster point and connect into inlets. Pump operator to charge lines and bring system up to operating pressure.

Drill 2 Flow attack delivery from the hydrant/booster outlets.

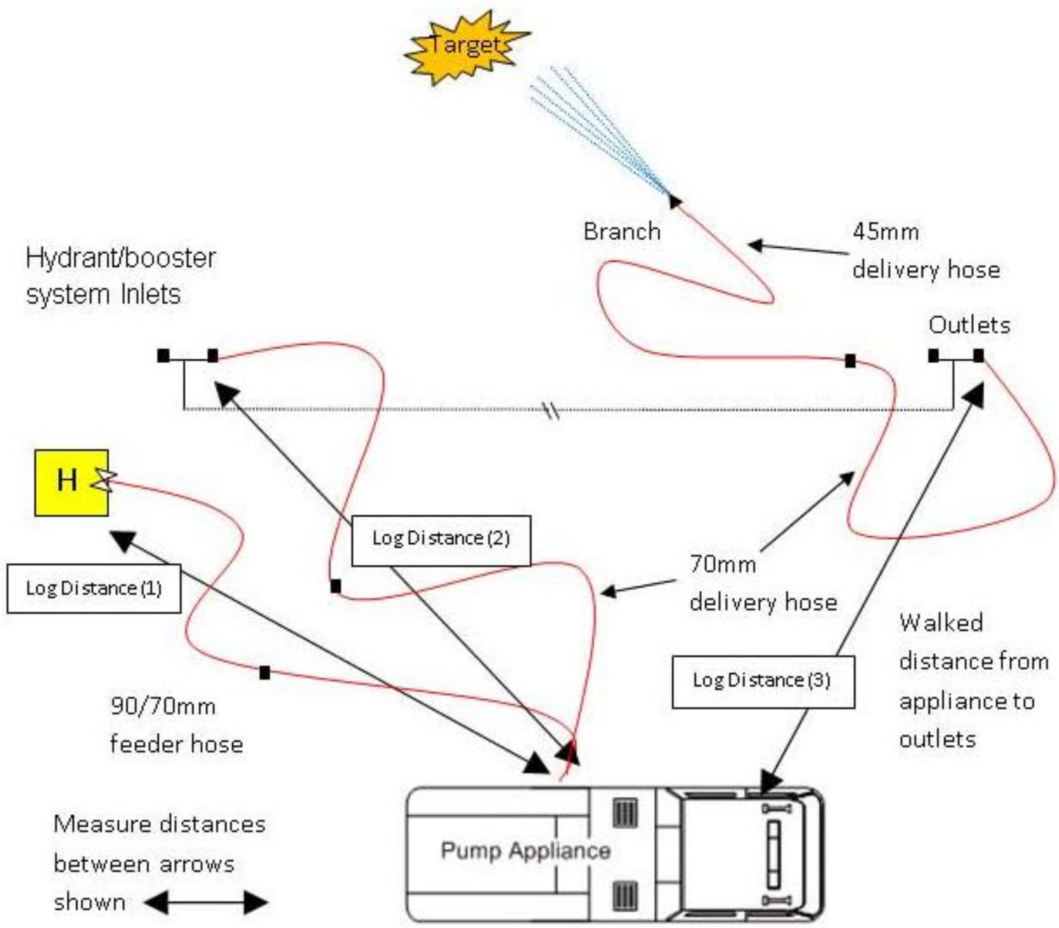
- Don BA, walk a measured distance and lay, 1 x 70mm and 1 x 45mm hose, charge system and flow attack line.

2 Fire fighters at signal from officer, dismount with BA donned (if using seat mounted BA otherwise remove BA from locker and don) as per SOP's. lodge BA tallies and complete BA control procedures at appliance, start BA at appliance or as a separate task before showing water.

Carry high rise hose pack to designated attack hydrant outlet, lay and charge hose, establish a working straight hose stream at stable appliance discharge pressure.

Measure and log distance of hydrant from appliance inlet, hydrant inlet/booster connections from appliance outlet, and walked distance from appliance to hydrant riser/booster outlets.

DIAGRAM OF DRILL



Drill 1 - Water supply to the appliance and hydrant/booster system inlets

Part 1 Driver /Pump Operator only		Time Start	Time Finish	Time Taken	Comments
Time to engage pump, dismount, gather necessary equipment to prepare hydrant for flow					
Time to travel to hydrant					
Time to prepare hydrant and flush					
If using flaked hose.	Time to charge ___ (No.) of 30/25m lengths feed hose of diameter ___mm				
	Return time to appliance from hydrant				
If using coiled hose.	Return time to appliance from hydrant				
	Time to unpack, connect and charge ___ (No.) of 30/25m coiled lengths of diameter ___mm.				
	Return time to appliance from hydrant				

Part 2 Fire-fighters or Driver/ Pump operator				
Time to dismount				
Time to unpack lay and connect _____ No. of 25m lengths of _______(coiled/flaked) hose of diameter_____to hydrant riser/booster inlet connections				
Time to bring delivery up to required pressure to charge system				

Drill 2 - Delivery from the appliance to hydrant/booster inlets

2 fire-fighters	Time Start	Time Finish	Time Taken	Comments
Time to dismount, remove and don BA and lodge tallies				
Time to unpack high rise pack (incl. branch 70mm and 45mm hose etc.) and walk to designated hydrant riser/booster outlet				
Time taken to don face mask, test seals, start BA, and complete safety checks				
Time to connect to hydrant riser/booster outlets, charge and flow attack line				

Please indicate:

1	Horizontal distance from appliance inlet to fire hydrant position (m)	
2	Horizontal distance from appliance outlet to hydrant riser/booster inlet (m)	
3	Walked distance from appliance to boosted hydrant riser /booster outlet (m)	
Brigade type		NZFS Permanent/ Volunteer/ Defence/ Rural

Exercise 3 Taking a hose up stairs

This exercise consists of 3 separate drills:

1. 2 fire fighters to ascend stairs with high pressure hose and show water, utilising water from the appliance only.

2. Establishing a water feed\delivery to the appliance.

3. 2 fire fighters to ascend stairs with low pressure hose and show water.

All fire fighters to be dressed in full level 2 uniform. One fire fighter to establish a feed\inlet from a fire hydrant to a pump appliance, two fire fighters shall set up an attack hose, hose to be taken up stairs and charged. The officer-in-charge will record times for each activity. All work to be carried out at normal fire ground speed. Use the high pressure hose reel for task 1 and at least one 45mm hose and sufficient 70mm diameter hose to connect to appliance.

Recommended resources

- Pump appliance with high pressure hose reel, officer and 3 fire-fighters
- BA for 2 fire fighters, sufficient lengths of hose
- Equipment to connect to the hydrant used (e.g. standpipe)
- Access to stairs (minimum 2 flights of stairs preferred)
- A wristwatch/stopwatch to record the time taken for each exercise in seconds
- A method of measuring the distances between the appliance and target (e.g. standpipe or building entry point).

Method

Drill 1 **2 fire fighters to ascend stairs with high pressure hose. When head of stairs reached show water. Water to be taken from the appliance only.**

Position an appliance within a measured distance of the stair entry. 2 Fire fighters at signal from officer, dismount with BA donned (if not using seat mounted BA remove BA from locker and don) as per SOP's, complete BA control procedures at appliance, lodge BA tallies. Ascend stairs with high pressure hose line, charge to operating pressure and show water. Measure and log distance to stair entry and log time to ascend and charge hose.

Drill 2 **Connect and charge sufficient lengths of feeder hose between a fire appliance and the nearest hydrant a measured distance from the inlet on the appliance.**

Position a pump appliance within reach of a fire hydrant and with sufficient space to lay and charge to operating pressure a low pressure delivery attack hose line. Measure the distances from the hydrant to the appliance, and from the appliance to the stair entry.

Driver engage pump (if cab control), alight, withdraw all necessary equipment to connect to the hydrant (e.g. standpipe, plate lifter, hydrant bar, turn keys), prepare hydrant for connection (e.g. ship standpipe, remove cap, flush), as per SOP's. If using coiled hose (please note) return for the lengths of coiled hose, connect hose and charge, return to appliance.

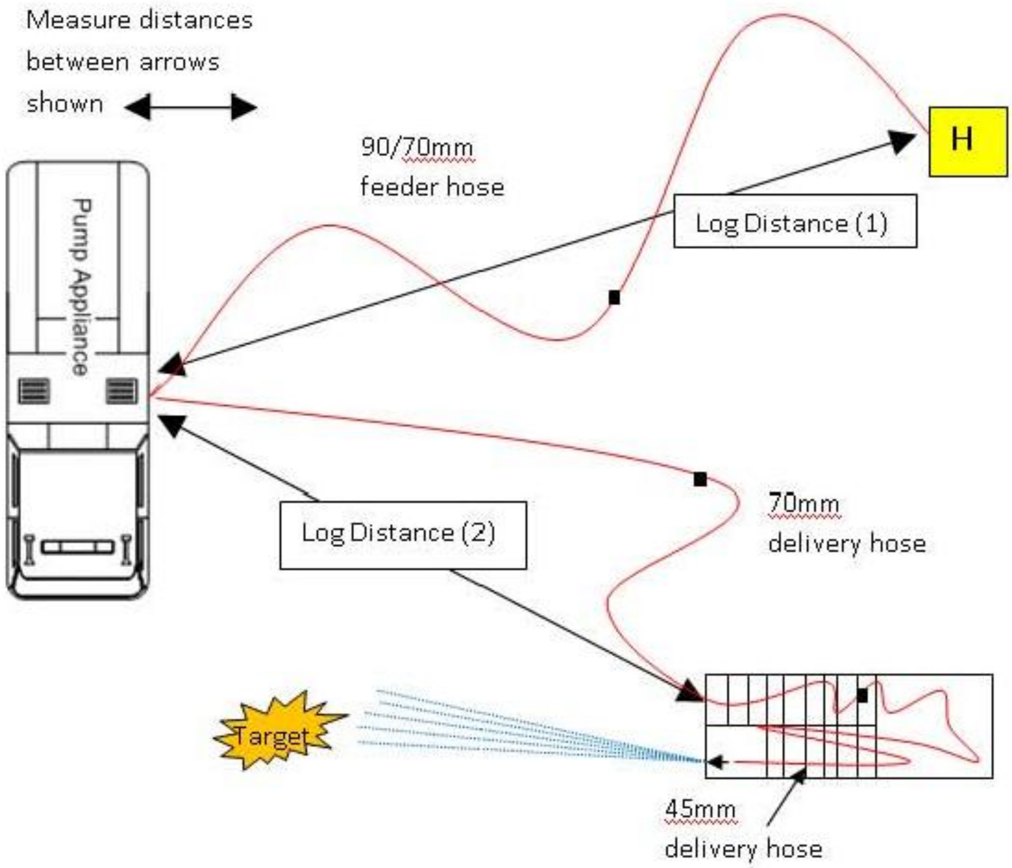
Drill 3 2 fire fighters to ascend stairs with low pressure hose and show water.

2 Fire fighters at signal from officer, dismount with BA donned (if not using seat mounted BA remove BA from locker and don) as per SOP's, complete BA control procedures at appliance, lodge BA tallies etc. Lay hose and ascend stairs to designated landing. Pump operator charge lines, show water when at required operating pressure. Measure and log distance to building entry point and number of stairs ascended. Where BA is not started at the appliance record location and time taken for this task separately.

Note:

It is recognised that BA may not be donned and started at the fire appliance as this may occur at the building entry point or similar when simulating real incident conditions. The data entry table provided on the following page acknowledges this aspect by providing two entries for these separate tasks. Where BA is not donned and started at the appliance please ensure that the times indicated within the table reflect the correct order of tasks completed.

DIAGRAM OF DRILL



Drill 1 High pressure hose reel - Stair Activity	Time Start	Time Finish	Time Taken	Comment
Time to dismount, remove, don BA and lodge tallies				
Time to ascend stairs with high pressure hose reel utilising the water tank on pumper only, charge and show water when at operating pressure				
Time taken to don face mask, test seals, start BA, and complete safety checks				

Note: Ensure that distances and number of steps are logged

Drill 2 - Driver/Pump Operator		Time Start	Time Finish	Time Taken	Comments
Time to engage pump, dismount, gather necessary equipment to prepare hydrant for flow					
Time to travel to hydrant					
Time to prepare hydrant and flush					
If using flaked hose.	Time to charge ___ (No.) of 30/25m lengths feed hose of diameter ___mm				
	Return time to appliance from hydrant				
If using coiled hose.	Return time to appliance from hydrant				
	Time to unpack, connect and charge ___ (No.) of 30/25m coiled lengths of diameter ___mm				
	Return time to appliance from hydrant				

Drill 3 - Attack Hose Up Stair Activity	Time Start	Time Finish	Time Taken	
Time to dismount, remove, don BA and lodge tallies				
Time to unpack lay and connect _____ no. of 25 m lengths of _______(coiled or flaked?) hose				
Time taken to walk to building entry point				
Time taken to ascend stairs and position hose on designated fire floor				
Time taken to don face mask, test seals, start BA, and complete safety checks				
Time to bring delivery up to required pressure and show water				
Time taken for any rest breaks				

Please indicate:

High pressure hose reel used		Length....... (m) and diameter....... (mm)
1	Horizontal distance from appliance inlet to fire hydrant position (m)	
2	Distance from appliance to stair entry point in drill 1(m)	
Total number of steps climbed and stair mid-landings		
Brigade type		NZFS Permanent/ Volunteer/ Defence/ Rural

Exercise 4 Personnel movement, including up stairs

2 Fire fighters to be dressed in full level 2 uniform with equipment and BA, walk a measured distance (approximately 50m), then ascend a number of stair flights (more than 3 is preferable). Conduct a relevant task (refer table), then descend stairs. Crew members to take appropriate rest times as necessary. All activities to be conducted simulating fire ground conditions.

Recommended resources

- Pump appliance with crew
- High rise pack or similar (minimum 1 length 45mm diameter hose, branch and other equipment)
- A stopwatch to record the time taken for each exercise in seconds
- A method of measuring the distances between the appliance and target (e.g. standpipe or building entry point).

Objective

To establish horizontal and vertical walking times, over measured distances, in BA and carrying equipment.

Method

Fire fighters at signal from officer, dismount with BA donned (if not using seat mounted BA remove BA from locker and don) as per SOP's, Gather high rise pack or similar forcible entry tools. Conduct BA procedures and safety checks at forward control point.

Walk measured horizontal distance to building entry point. Ascend measured stairs at normal walking speed. Undertake a task such as connecting and deployment of hose line (dry) and prepare for use. Descend stairs at normal walking speed.

Note:

It is recognised that BA may not be donned and started at the fire appliance as this may occur at the building entry point or similar when simulating real incident conditions. The data entry table provided on the following page acknowledges this aspect by providing two entries for these separate tasks. Where BA is not donned and started at the appliance please ensure that the times indicated within the table reflect the correct order of tasks completed.

Personnel Movement Activity	Start time	Finish time	Time taken	Comments
Time taken to dismount appliance, remove and don BA				
Time taken to start BA, conduct procedures and complete safety checks				
Time taken to remove high rise pack or similar				
Time taken to walk to building entry point				
Time taken to ascend stairs and reach designated fire floor				
Time taken for any rest breaks				
Task example: time taken to deploy and connect hose line to building hydrant				
Time taken to descend stairs				
Total time if completed as a single exercise (optional)				

Please indicate:

Horizontal distance from appliance to building entry point (m)	
Total number of steps climbed and stair mid-landings	
Brigade type	NZFS Permanent/ Volunteer/ Defence/ Rural

Exercise 5 Search and rescue

Search and rescue is the most essential component of the data collection requirements and this exercise should be treated as a priority.

All fire fighters to be dressed in full level 2 gear, including BA with obscured face mask, in blacked out room or large space to simulate heavy smoke logging conditions. A 2 member team shall conduct a search of the room/space using either perimeter based or area based search techniques depending on the size of the room/space. Typical furnishings and/or fixtures and contents are required to be randomly placed in the room/space. Any rest periods necessary during the exercise (e.g. due to ascending stairs) should be taken and recorded.

Recommended resources

- 2 Search teams consisting of 2 people in full level 2 uniform and BA
- Guide Lines
- Adult size dummy
- Obscured face masks (e.g. sand blasted) so that torch glow is apparent
- Blacked out room/spaces of various sizes
- A wristwatch/stopwatch to record the time taken for each exercise in seconds
- A method of measuring the search distances and size of the building.

Objective

to determine the time taken to:

- conduct an internal search in smoke filled conditions
- retrieve an incapacitated victim
- travel in a smoke logged environment both horizontally and vertically
- establish the size of a search area when a perimeter based search is no longer applicable and other procedures (e.g. guide lines) are required

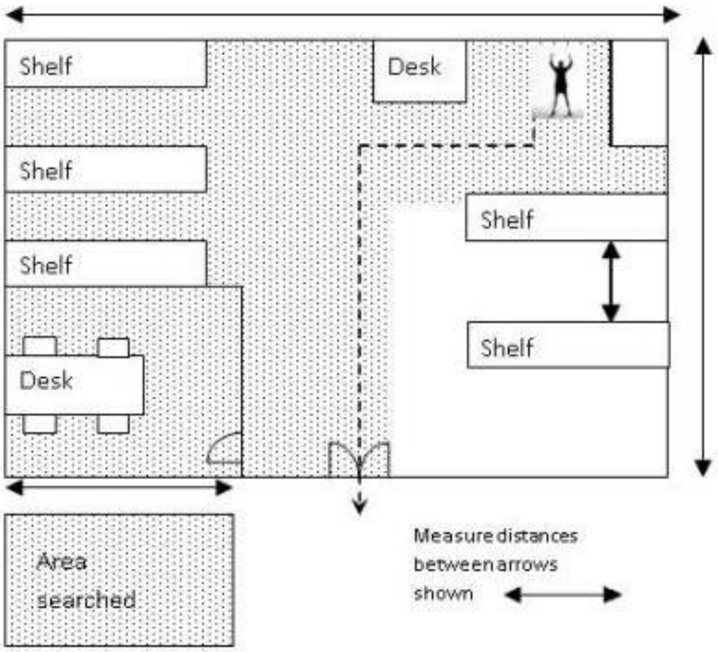
Method

It should be possible to conduct this exercise in a variety of locations (preferably off station after prior arrangement with building owners) as obscured face masks are being used in lieu instead of smoke. The procedures should be conducted in typically furnished occupancies so as to replicate real life situations. As many types of buildings as possible should be utilised, large and small, for example offices, shops, warehouses, factories, hospitals, theatres, apartments, hotels, etc.

The officer in charge shall note the times from entry into enclosure until exit from enclosure with any necessary comments as deemed appropriate.

Drill 1 Search of smoke logged area

- please provide a sketch of each enclosure searched including dimensions and location of doors, furnishings, and other obstructions or points of interest; e.g.:



- conduct a search appropriate to the size of the room/space as per usual procedures (indicate if guide lines used)

NB If search of area is incomplete due to BA duration, indicate on the diagram what area has been searched. The drill must be completed with team of 2 fire fighters and where possible repeated with multiple teams.

Drill 2 Simulated rescue of victim

- position an adult size dummy (victim) to be rescued a measured distance remote from the enclosure exit point
- send in a different search team to that which completed drill 1 and record area searched until victim located
- record time to locate dummy, time to remove dummy once found, and measure actual distance travelled in removing dummy to the exit

Drill 3 Vertical movement

record the time taken for 2 fire fighters, wearing BA with obscured face masks, to carry a high rise pack or similar to:

- ascend, and descend a recorded number of steps or treads (risers)

Note: A typical case would be 3 flights of stairs.

Notes for the Officer in charge

Note that the comments are necessary to clarify issues, such as the way the dummy was removed. It is necessary to use a different crew in drill 2, because the crew in drill 1 already has a familiarity with the enclosure. Realistic times for search and rescue are essential for the data.

Sketch of searched building/room

Activity	Start time	Finish time	Time taken	Comments
Drill 1				
Time taken to search perimeter (if applicable)				
Total time taken to complete search				
Drill 2				
Time taken to locate dummy				
Time taken to remove dummy from enclosure				
Drill 3				
Time taken to ascend stairs				
Time taken for any rest period				
Time taken to descend stairs				

Please indicate:

Search method employed - perimeter/other (please specify)	
Were guide lines used for area search - yes/no	
Were protective hose lines used - yes/no	
Distance the victim was moved to building exit point (m)	
Total number of steps climbed and stair mid-landings	
Brigade type	NZFS Permanent/ Volunteer/ Defence/ Rural

Exercise 6 Aerial appliance set up

All fire fighters to be dressed in full level 2 uniform. The aerial appliance driver shall be instructed to position the appliance at a certain location. The aerial appliance is then set up to simulate typical fire ground duties which includes extending and rotating the ladder/basket to its maximum reach. All safety procedures are to be completed. The procedure should include an aerial operator(s) to don BA, and this time is to be logged. Fire fighters will also connect water hose lines from source to monitor, or from source to pump appliance to monitor depending on the appliance type. All activities to be conducted simulating typical fire ground conditions

Recommended resources

- Aerial appliance with crew
- pump appliance
- BA for aerial operator(s)
- 6 x 30/25m lengths (2x 90mm & 4x 70mm diameter hose)
- A wristwatch/stopwatch to record the time taken for each exercise in seconds
- A method of measuring the distances between the appliance and target (such as the standpipe).

Objective

To establish the time taken to:

- Position and set up an aerial appliance and charge hose lines and monitor
- Elevate to full height and train 180°

Note:

This exercise has been split into 3 separate Drills:

Drill 1 is to be used for an aerial appliance with no pump appliance support required.

Drill 2 establishes the time taken to supply water to the pump appliance

Drill 3 establishes the time taken to connect the aerial appliance to the pump, complete aerial set up and flow water through the monitor(s).

Drill 2 follows the same format as the hose drill exercise set out in the FBIM exercise 1 example and is designed to be undertaken separately to drill 3.

Method

Appliances with crews dressed in full level 2 uniform. Site the appliance at a position nominated by the OIC. The crew should not be aware of the location until instructed by the OIC. Set levelling devices, remove necessary equipment and implement appropriate safety procedures. Remove and don BA as required.

Aerial operator shall elevate appliance to full height and train 180° (as per normal operation). Connect and charge inlet hose from hydrant to pump or pulpit connections and charge monitor.

Diagram of drill 1 (without pump appliance)

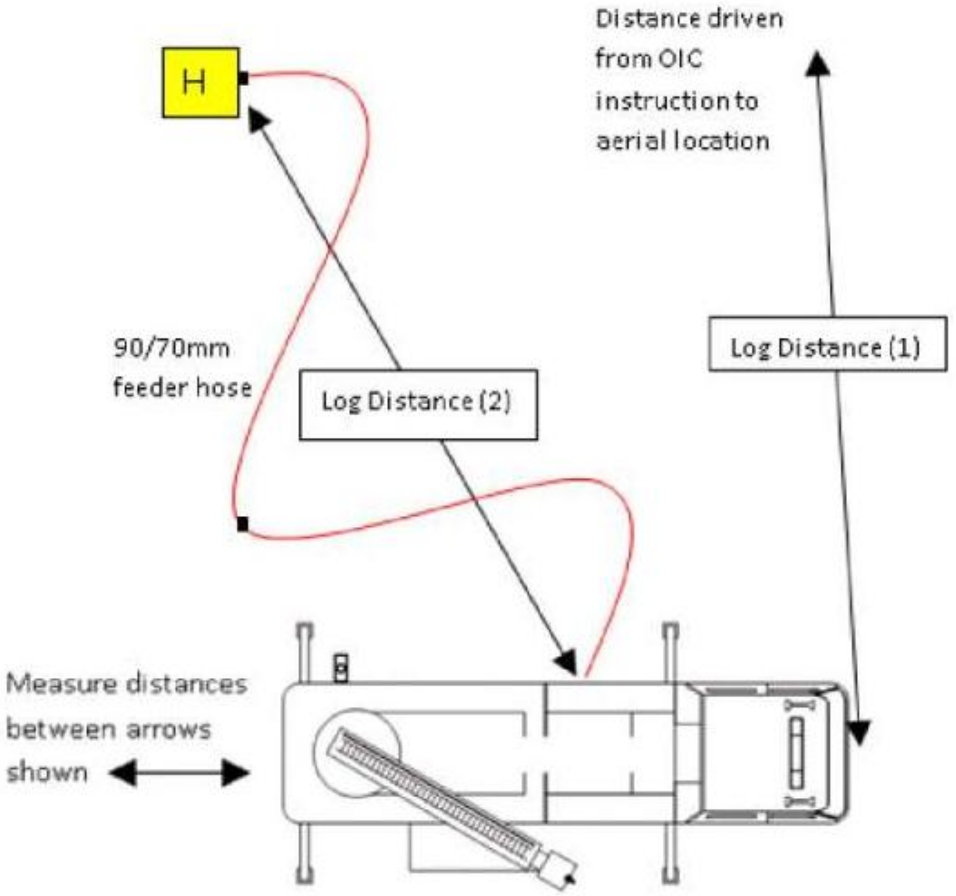
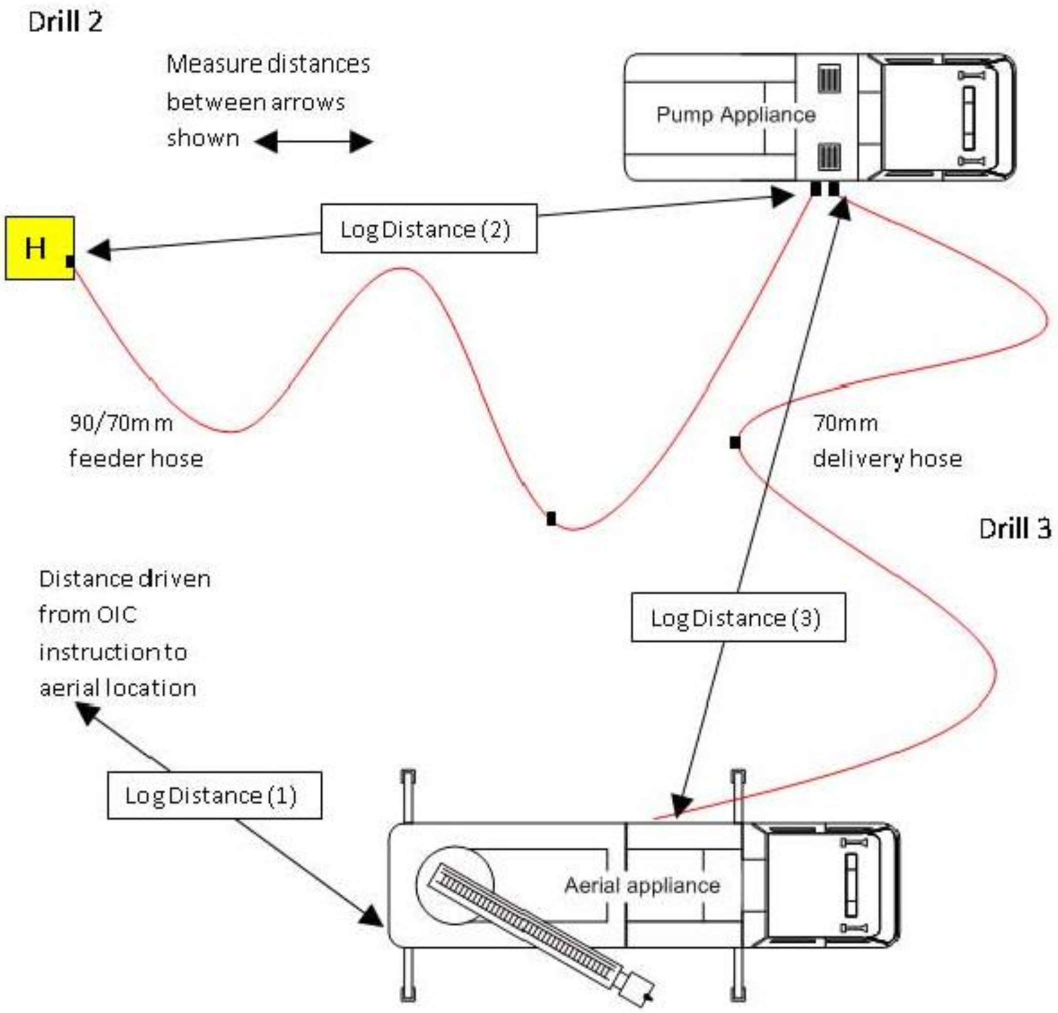


Diagram of drill 2 and 3 with pump appliance



Drill 1 Aerial Appliance Activity without pump appliance

Tasks	Start time	Finish time	Time taken	Comments
Time taken to site appliance after instruction from officer in charge				
Time taken to set levelling devices and remove necessary equipment				
Time taken to implement safety procedures; e.g. don harnesses				
Time taken to remove and don BA				
Time taken to elevate appliance and train 180^0				
Time to charge ___ (No.) of 30/25m lengths feed hose of diameter ___mm hydrant to appliance				
Time taken to charge monitor and show water				

Please indicate:

1	Distance from where instruction was given to appliance set up location (m)	
2	Distance from hydrant to pump or aerial appliance (m)	
Aerial appliance type...elevation height (m)................feeder hose diameter (mm).........		
Brigade type		NZFS Permanent / Volunteer

Drill 2 Hose Drill Activity

Tasks - Driver /Pump Operator only		Time Start	Time Finish	Time Taken	Comments
Time to engage pump, dismount, gather necessary equipment to prepare hydrant for flow					
Time to travel to hydrant					
Time to prepare hydrant and flush					
If using flaked hose.	Time to charge ___ (No.) of 30/25m lengths feed hose of diameter ___mm				
	Return time to appliance from hydrant				
If using coiled hose.	Return time to appliance from hydrant				
	Time to unpack, connect and charge ___ (No.) of 30/25m coiled lengths of diameter ___mm				
	Return time to appliance from hydrant				

Please indicate:

2	Horizontal distance from appliance inlet to fire hydrant position (m)	
Brigade type		NZFS Permanent / Volunteer

Drill 3 Aerial Appliance with pump appliance

Tasks	Start time	Finish time	Time taken	Comments
Time taken to site aerial appliance after instruction from officer in charge				
Time taken to set levelling devices and remove necessary equipment				
Time taken to implement safety procedures; e.g. don harnesses				
Time taken to remove and don BA				
Time taken to elevate appliance and train 180^0				
Time to charge ___ (No.) of 30/25m lengths feed hose of diameter ___mm pump to aerial appliance				
Time taken to charge monitor				

Please indicate:

1	Distance from where instruction was given to appliance set up location (m)	
2	Distance from hydrant to pump or aerial appliance (m)	
3	Distance from pump appliance to aerial appliance (where applicable) (m)	
Aerial appliance type...elevation height (m)................feeder hose diameter (mm).........		
Brigade type		NZFS Permanent / Volunteer

Exercise 7 Obtaining water from non reticulated supply

Object

To establish time to:

- position appliance for open water or static supply
- connect and secure suction hose to appliance
- connect and secure suction hose to open water or static supply
- prime suction lines

Recommended resources

- Pumping appliance with officer crew
- Suction hose and associated equipment (strainer) minimum 2 lengths
- A wristwatch/stopwatch to record the time taken for each exercise in seconds
- A method of measuring the distances between the appliance and target (such as the standpipe).

Method

Drill 1 Open water source

Appliances with crews dressed in full level 2 uniform. At instruction from OIC, position appliance adjacent to water source (minimum 20 m travel to open water source is desirable).

Remove necessary equipment, connect suction hoses to appliance and secure with rope line as per standard operating procedures.

Lower strainer into open water source and secure.

Prime suction hose.

Drill 2 Static water source

Appliances with crews dressed in full level 2 uniform. At instruction from OIC, position appliance adjacent to static tank suction connection (minimum 20 m travel to suction connection desirable).

Remove necessary equipment, connect hose to appliance

Connect hose to static water connection

Prime suction hose.

Static water source activity	Time Start	Time Finish	Time Taken	Comments
Drill 1				
Time taken to position appliance adjacent to water source from start point (minimum 20 m)				
Time taken to remove suction hose and connect to appliance				
Time taken to secure hard suction with rope line				
Time taken to lower and prime suction hose				

Drill 2				
Time taken to position appliance adjacent to static water connection from start point (minimum 20 m)				
Time taken to remove suction hose, connect to appliance and connect to static suction connection				
Time taken to prime suction hose				

Please indicate:

Distance from where instruction was given to water source	
Number of lengths of suction hose used (125mm diameter)	
Brigade type	NZFS Permanent / Volunteer / Defence / Rural

Exercise 8 Hazmat

Fire fighters to be initially dressed in full level 2 uniform. 2 fire fighters to don encapsulated suits and BA and walk a measured distance (approximately 50 m). Conduct task as appropriate (refer table). Crew members to take appropriate rest times as necessary. All activities to be conducted under simulated fire ground conditions.

Recommended resources

- Appliance with crew
- Hazardous incident gear and associated equipment
- A wristwatch/stopwatch to record the time taken for each exercise in seconds
- A method of measuring the distances between the appliance and target (such as the standpipe).

Objective

To establish preparation time for a dangerous goods incident and for horizontal and vertical walking times over measured distances in BA and hazardous incident gear (e.g. encapsulated suit).

Method

Appliances with crews dressed in full level 2 uniform. Dismount appliance, remove and don BA and hazardous incident suit. This will necessitate the removal of level 2 uniform and should be included in the time taken.

Conduct BA procedures and safety checks, final donning of hazardous incident suit and prepare other equipment as appropriate and relevant to normal procedures.

Walk measured horizontal distance to simulated chemical incident. A distance of approximately 50 m should be selected.

Notify crew at this time that the hazardous material is methane gas - CH_4, class 2.1, Hazchem code 2SE, UN no. 1971. Time the process of obtaining hazardous material information from an electronic database using Hazmat Action Guide; i.e. via communication centre.

Hazmat activity	Start time	Finish time	Time taken	Comments
Time taken to dismount appliance and remove and don BA and hazardous incident suit				
Time taken to conduct BA procedures, complete safety checks and final suit donning				
Time taken to assemble required safety equipment (if applicable)				
Time taken to walk measured horizontal distance				
Time taken to obtain hazardous material information from com-centre				
Total time if completed as a single exercise (optional)				

Please indicate:

Horizontal distance from appliance to incident location (m)	
Safety equipment used (e.g. shower, recovery drums, etc.)	
Brigade type	NZFS Permanent / Volunteer

Appendix H

High Rise Stair Climbing Raw Data

Table 56 Individual high-rise stair climber times

Fire fighter	Start time	Stair entry	Level 5	Level 10	Level 15	Level 20	Level 25	Level 28
1	0:00:00	0:00:21	0:01:34	0:03:49	0:05:57	0:08:35	0:12:22	0:14:04
2	0:00:00	0:00:15	0:01:04	0:02:33	0:03:58	-	0:08:09	0:09:16
3	0:00:00	0:00:18	0:01:12	0:02:22	0:03:31	0:05:04	0:06:17	0:07:13
4	0:00:00	0:00:23	0:01:23	0:02:22	0:03:51	0:05:18	0:06:38	0:07:38
5	0:00:00	0:00:23	0:01:29	0:03:09	0:05:27	-	0:09:51	0:11:23
6	0:00:00	0:00:16	0:01:14	0:02:20	0:04:09	0:05:36	0:09:25	0:10:43
7	0:00:00	0:00:27	0:01:24	0:02:36	0:04:03	0:05:39	0:07:12	0:08:25
8	0:00:00	0:00:18	0:01:23	0:02:40	0:03:57	0:05:33	0:06:52	0:08:00
9	0:00:00	0:00:20	0:06:21	0:07:48	0:09:59	0:12:47	0:16:26	0:18:15
10	0:00:00	0:00:32	0:01:23	0:02:45	0:04:15	0:05:33	0:07:19	0:08:28
11	0:00:00	0:00:13	0:00:53	0:02:14	0:03:29	0:04:35	0:05:53	0:06:43
12	0:00:00	0:00:14	0:01:00	0:02:21	0:03:43	0:05:06	0:06:35	0:07:44
13	0:00:00	0:00:16	0:01:14	0:02:09	0:03:54	0:05:15	0:09:25	0:10:41
14	0:00:00	0:00:20	0:01:20	0:02:46	0:04:02	0:05:50	0:07:42	0:09:03
15	0:00:00	0:00:22	0:01:24	-	0:04:54	0:06:58	0:09:23	0:10:48
16	0:00:00	0:00:23	0:01:24	0:02:36	0:03:49	-	0:06:12	0:07:03
17	0:00:00	0:00:21	0:01:51	-	0:06:40	0:10:04	0:13:07	0:15:10
18	0:00:00	0:00:16	0:01:16	0:03:00	0:04:41	0:08:39	0:11:34	0:12:49
19	0:00:00	0:00:18	0:01:14	0:02:20	0:04:15	0:05:43	0:09:34	0:10:55
20	0:00:00	0:00:22	0:01:05	0:02:15	0:03:38	0:05:03	0:06:32	0:07:32
21	0:00:00	0:00:12	0:01:10	0:02:13	0:03:43	0:05:12	0:06:43	-
22	0:00:00	0:00:23	0:01:20	0:02:22	0:03:37	0:04:57	0:06:06	0:07:12
23	0:00:00	0:00:39	0:01:31	0:02:46	0:04:10	0:05:39	0:07:25	0:08:29
24	0:00:00	0:00:12	0:01:06	0:02:13	0:03:43	0:05:22	0:06:36	0:07:54
25	0:00:00	0:00:18	0:01:08	0:02:17	0:03:47	0:05:26	0:06:40	0:07:56
26	0:00:00	0:00:14	0:01:04	0:02:17	0:03:40	0:05:26	0:06:31	0:07:54
27	0:00:00	0:00:18	0:01:18	0:02:34	0:04:03	0:05:26	0:06:55	0:08:08
28	0:00:00	0:00:19	0:01:16	0:02:39	0:03:40	0:04:56	0:06:01	0:07:14
29	0:00:00	0:00:39	0:01:28	0:02:46	0:03:58	0:05:39	0:07:19	0:08:23
30	0:00:00	0:00:14	0:00:43	0:02:00	0:03:14	0:04:30	0:05:47	0:06:43
31	0:00:00	0:00:26	0:01:24	0:02:45	-	0:06:36	0:08:16	0:09:38
32	0:00:00	0:00:23	0:01:18	0:02:22	0:04:15	0:06:07	0:08:08	0:11:18

33	0:00:00	0:00:34	0:01:21	0:02:32	0:04:00	0:05:03	0:07:20	0:08:40
34	0:00:00	0:00:25	0:01:33	0:02:45	0:04:02	0:05:33	0:07:08	0:08:01
35	0:00:00	0:00:30	0:01:42	0:02:45	0:04:10	0:05:33	0:07:26	0:08:31
36	0:00:00	0:00:20	0:01:28	0:02:45	0:04:02	0:05:33	0:07:08	0:08:22
37	0:00:00	0:00:19	0:01:16	0:02:45	0:03:59	0:05:49	0:07:30	0:08:58
38	0:00:00	0:00:23	0:01:18	0:02:22	0:04:21	0:05:32	0:07:04	0:08:08
39	0:00:00	0:00:34	0:01:17	0:02:32	0:03:56	0:05:03	0:06:32	0:07:39
40	0:00:00	0:00:18	0:01:10	0:02:47	0:06:49	0:11:18	0:15:31	0:17:08
41	0:00:00	0:00:27	0:01:09	0:02:20	0:03:19	0:04:28	0:05:38	0:06:35
42	0:00:00	0:00:12	0:01:04	0:02:20	0:04:03	0:05:43	0:09:25	0:10:51
43	0:00:00	0:00:18	0:01:20	0:02:47	0:06:51	0:11:14	0:15:31	0:17:13
44	0:00:00	0:00:18	0:01:20	0:03:23	0:06:56	0:11:20	0:15:31	0:17:10
45	0:00:00	0:00:25	0:01:54	0:03:38	0:06:04	0:08:40	0:13:05	0:13:59
46	0:00:00	0:00:21	0:01:43	0:03:47	0:05:46	0:08:27	0:12:08	0:13:51
47	0:00:00	0:00:26	0:01:31	0:02:50	0:04:57	0:06:24	0:08:28	0:09:41
48	0:00:00	0:00:23	0:01:08	0:02:33	0:03:48	0:04:59	0:06:22	0:07:23
49	0:00:00	0:00:43	0:01:35	0:02:44	-	-	0:06:03	0:06:50
50	0:00:00	0:00:26	0:01:18	0:02:27	0:03:26	0:04:32	0:05:40	0:06:45
51	0:00:00	0:00:26	0:01:38	0:02:58	0:03:44	0:04:43	0:05:36	0:06:21
52	0:00:00	0:00:16	0:01:16	0:02:34	0:04:03	0:05:26	0:06:47	0:08:05
53	0:00:00	0:00:21	0:01:09	0:02:30	0:03:56	0:05:34	0:07:15	0:08:41

Appendix H

Fire Ground Field Experiment Results

Table 57 Exercise A results

Activity	Minutes	Seconds
Mobilised	0.00	0
First appliance in attendance	0.00	0
Fire fighters dismount	0.33	20
Breathing apparatus removed from appliance	1.10	66
Breathing apparatus removed placed on ground ready to don	1.37	82
Fire fighters begin search for hydrant	1.47	88
Removal of feeder hose and starting of "standpipe shipped to hydrant"	1.50	90
Reach hydrant	2.30	138
Fire fighter 1 leave hydrant	2.83	170
Fire fighter 1 return to truck	3.30	198
Fire fighter 2 with feeder hose connected leave hydrant	4.40	264
Breathing apparatus procedure starts fire fighter 1	4.73	284
Breathing apparatus procedure starts fire fighter 2	4.82	289
3rd/4th appliances arrive	5.00	300
Breathing apparatus procedure, donned not started fire fighter 1	5.35	321
Fire fighter 1 removes high rise pack from truck and carries to building entry point	5.37	322
Breathing apparatus procedure donned not started fire fighter 2	5.88	353
3rd appliance arrives and parks up	5.57	334
Breathing apparatus procedure donned not started fire fighter 3	7.08	425
Breathing apparatus procedure donned not started fire fighter 4	7.18	431
Breathing apparatus procedure donned not started fire fighter 5	7.20	432
Breathing apparatus entry control board established		
Breathing apparatus procedure started fire fighter 1	8.73	524
Breathing apparatus procedure started fire fighter 2	8.73	524
Breathing apparatus procedure complete fire fighter 1	10.12	607
Breathing apparatus procedure complete fire fighter 2	10.23	614
Door entry practises	10.23	614
Entrance to building made	10.68	641
Fire fighter 3 and 4 enter building	12.37	742
Fire fighter 1,2,3,4 enter ground floor stair	12.90	774
Fire fighter 3,4 at head of stair	13.68	821
Searching management room	16.40	984
Casualty found	20.15	1209
Casualty at head of stairs	20.98	1259
Casualty at foot of stairs	21.67	1300
Breathing apparatus procedure started fire fighter 5	21.82	1309
Breathing apparatus procedure started fire fighter 6	21.82	1309
First breathing apparatus whistle sounds	22.28	1337

Casualty dragged to entrance	22.65	1359
Fire fighters leave entrance	22.90	1374
Breathing apparatus procedure complete fire fighter 5	22.88	1373
Breathing apparatus procedure complete fire fighter 6	24.18	1451
Fire fighter 5,6 take in extra hose from entrance	24.65	1479
Fire fighter 1,2 leave entrance	25.20	1512
Fire fighter 5,6 take in extra hose from entrance arrive at foot stair	25.35	1521
Fire fighter 5,6 enter head of stair	25.72	1543
2 fire fighters enter rear warehouse and follow guideline	29.07	1744
2 fire fighters reach foot of 2nd stair	30.18	1811
2 fire fighters reach head of 2nd stair	30.53	1832
Fire fighters reach outside of management conference room	31.58	1895
2nd casualty reaches head of stair	33.23	1994
2nd casualty reaches foot of stair with 4 fire fighter 's	34.13	2048
2nd casualty reaches exit of warehouse with 4 fire fighter 's	34.92	2095
Exercise end		

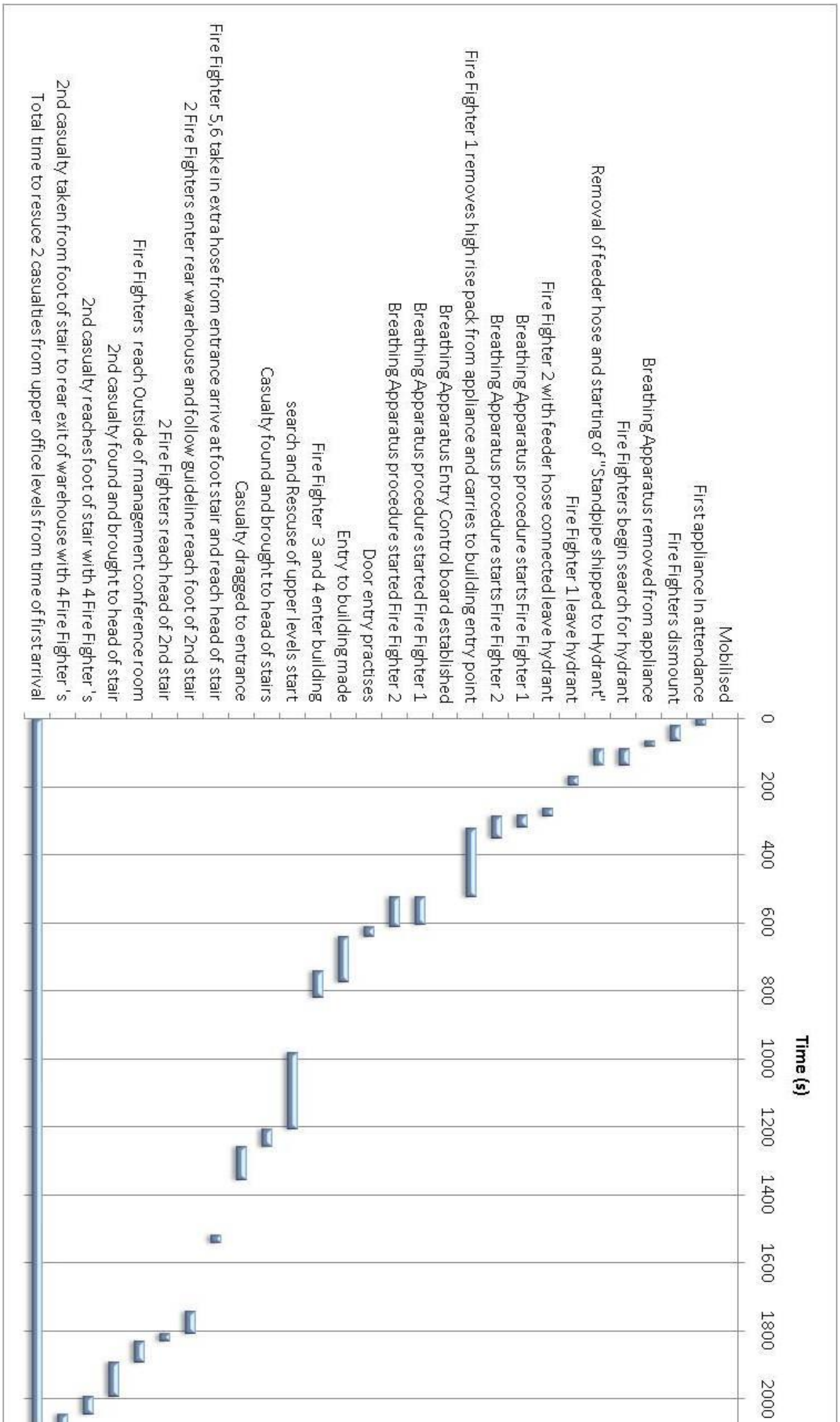


Figure 80 Overall time taken to rescue 2 casualties in Exercise A

Table 58 Exercise B results

Activity	Minutes	Seconds
1st appliance in attendance		
Pump operator collects hydrant tools	0.14	14
Fire fighter 1 removes 75 mm delivery hose	0.18	18
Pump operator starts to run out feeder hose to hydrant	0.38	38
Fire fighter 1 reaches office entrance with flaked hose	0.36	36
75 mm lp delivery hose by front door, 3x75 mm flaked lengths	1.18	78
Pump operator reaches hydrant - 90 mm flaked feeder hose dragged across grass 57 m approx.	1.45	105
Pump operator flushes hydrant	2.15	135
Reading fire alarm panel	2.43	163
Water supply - hydrant turned on and connected to appliance	3.03	183
Feeder hose charged - appliance has water supply	3.36	216
Delivery hose extended by 1 length, now 3x75 mm and 1x45 mm	4.20	260
Fire fighter 1 and 2 start donning breathing apparatus	4.28	268
1st breathing apparatus crew - donned and started - 'on air'	5.22	322
Start charging deliveries	6.54	414
Delivery charged - 3x75 mm and 1x45 mm hose	7.35	455
2nd appliance and aerial appliance in attendance	7.42	462
Fire fighter 1 and 2 in breathing apparatus enter building with charged jet	7.56	476
2nd low pressure delivery at the door	13.01	781
Fire fighter 1 and 2 reach top of stairs and door entrance	13.45	825
2nd breathing apparatus crew enter building to advance 1st hose line	15.29	929
3rd and 4th appliance in attendance (3rd alarm) - breathing apparatus tender and control unit arrive and set up	20.41	1241
1st victim/ dummy recovered at had of stairs		1720
Auckland appliance in attendance	28.50	1730
Dummy fire fighter rescued from 1st floor level down stairs, time taken at ground floor, dragged to building entry point	30.04	1804
Exercise end		

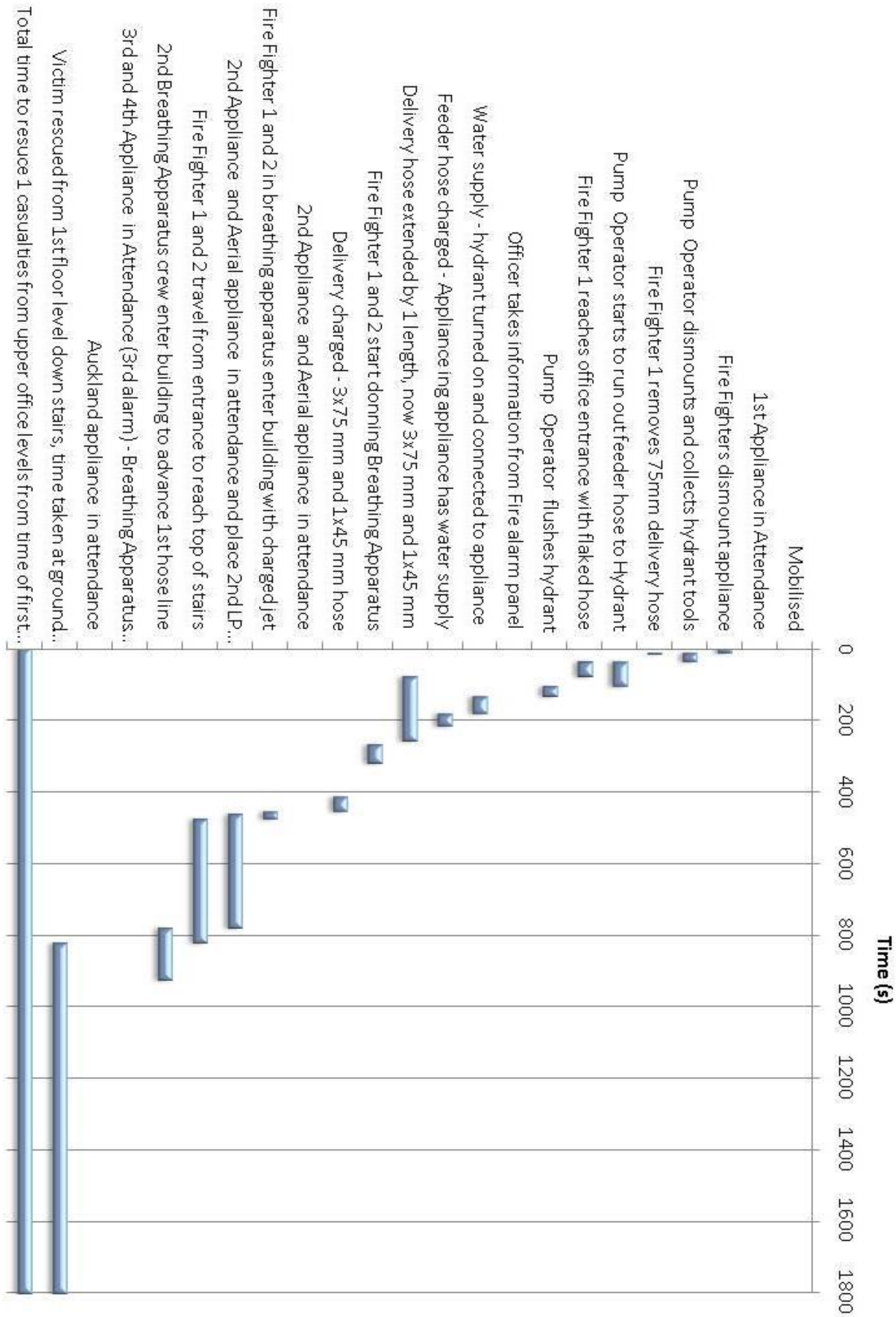


Figure 81 Overall time taken to rescue two casualties in exercise B

Appendix I

FBIM Computer Program Results

Table 59 FBIM computer program results for Exercise B using Australian data and 95th percentile confidence limits

Australasian Fire Authorities Council - Fire Brigade Intervention Model				
Version 1.03 Beta ©2010 AFAC				
Run Log for crew# 1				
Activity	Chart	Start Time	Duration	End Time
Time for alarm verification	1			
An automatic direct	uninterrupted connection to the fire brigade is provided			
Time to receive call - via automatic call	2			
Time to dispatch	2			
Dressing & assimilation included in brigade response speeds	3			
Brigade policy response time	4			
Time to don BA	6	0	145	145
longest concurrent safety procedure to complete	6	145		145
high rise pack or similar	6	145	23	168
longest concurrent tool obtaining procedure to complete	6	168	62	230
Delay time for forced entry	5	230		230
Delay time for door entry	5	230	10	240
Brigade planning not documented - Time to resolve way-finding	5	240	30	270
Specific activity travel in Chart 9 not employed	reverting to default			
Delay time for opening doors through 1 door(s) of type Side hung door	9	270	10	280
Time for horizontal travel	9	280	117	397
Time for vertical travel up stairs	9	397	66	462
Time for information gathering from FIP	5	462	30	492
Time for OIC to travel around perimeter	7	492		492
Based on initial assessment of fire OIC calls for additional resources	7	492		492
Delay for security procedures to travel on site	8	492		492
Road travel required on the site - 0 m @ 8 km/h	8	492		492
Delay for internal security procedures to travel on site	8	492		492
Specific activity travel in Chart 9 not employed	reverting to default			
Delay time for opening doors through 1 door(s) of type Side hung door	9	492	10	502
Time for horizontal travel	9	502	117	619
Time for vertical travel up stairs	9	619	66	685

Adjustment for delays due to evacuation hindrance factor	8	685		685
Attack hose from appliance to branch	11	685	68	752
Time to travel horizontally with initial setup protection	10	752	117	869
Time to travel up stairs with initial setup protection	10	869	24	893
Commencing perimeter search of fire compartment	12	893		893
Perimeter search completed	12	893	1	894
Area search completed before arrived on scene	12	894		894
Total time to make entry to upper floor		0	894	

----

end of log....

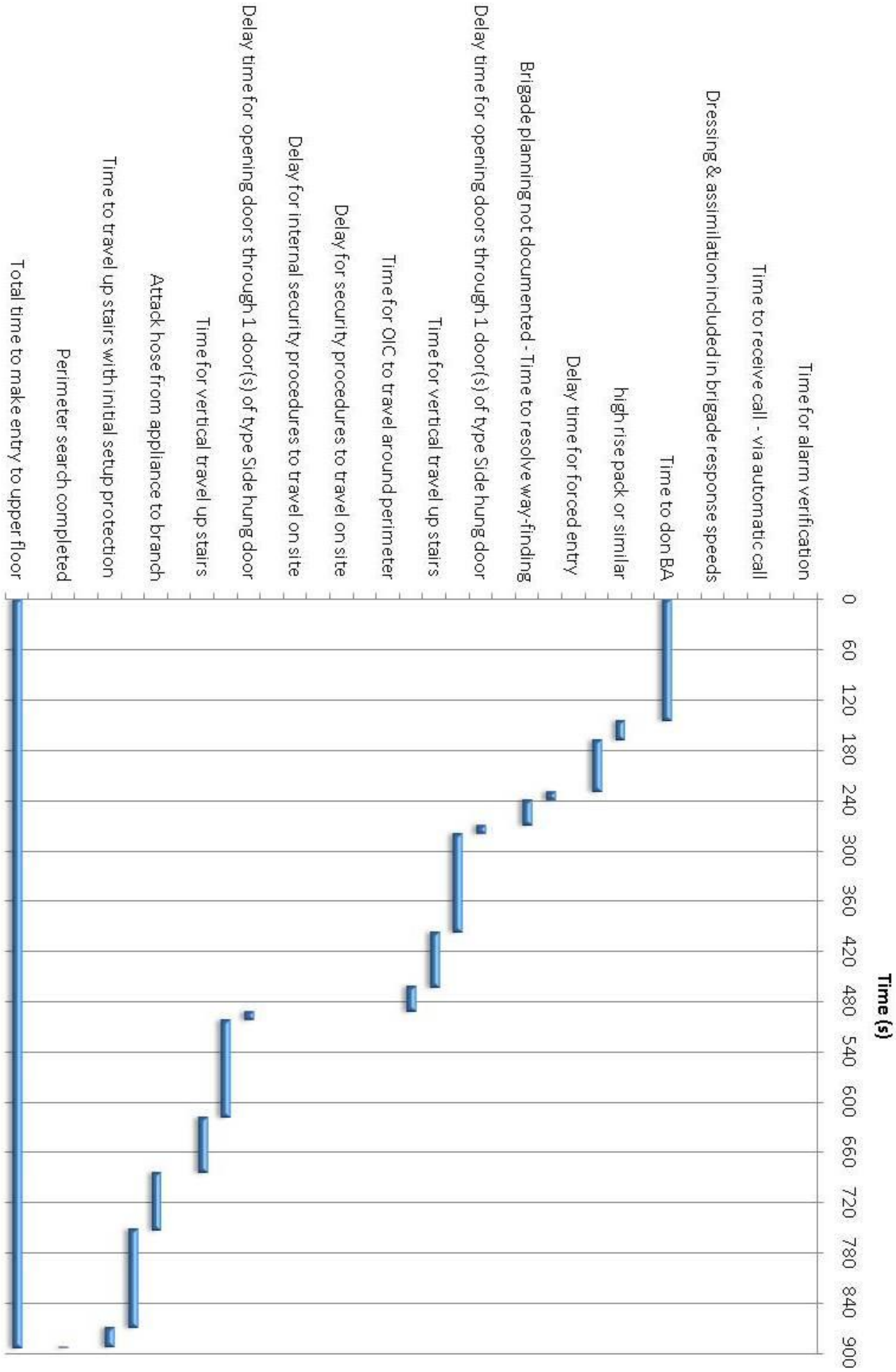


Figure 82 FBIM computer model results for simulated Exercise B using 95th percentile distribution

Appendix J

NZFS Operational Standard. High-rise Procedures

High-rise Procedures

References

Operational Instruction *S1Multi-storied buildings*.

Regional Standard Operating Procedures.

Don structural firefighting uniform and BA. Crew uplift high-rise kit.

Pump operator to establish water supply and be ready to charge riser if directed.

Proceed to a safe floor, normally the floor below the fire. Lifts may be used only with the permission of the OIC.

Safety Note

When carrying hose, ensure that it is carried in a safe and comfortable manner.

OIC and crew investigate fire floor and carry out assessment.

Fire?

No

OIC notifies responding crews to stand down.

Yes

Return to floor below and establish forward control point. BA tallies in high-rise board. Establish delivery and proceed to the fire floor and fight fire.

Safety Note

Always maintain a secure escape route.

Second responding crew, same duties as first crew. Access from different stairwell if possible. If not, back up first crew.

Third responding crew, proceed to forward control point and carry out search and rescue of floors above the fire.

Fourth responding crew, ensure riser is charged and then set up lobby control.

Information

At protracted incidents, there are likely to be three control centres:

- Forward control point (ECO, forward staging, and emergency crews)
- Lobby control (coordinating personnel and equipment)
- Incident command (command unit away from building).

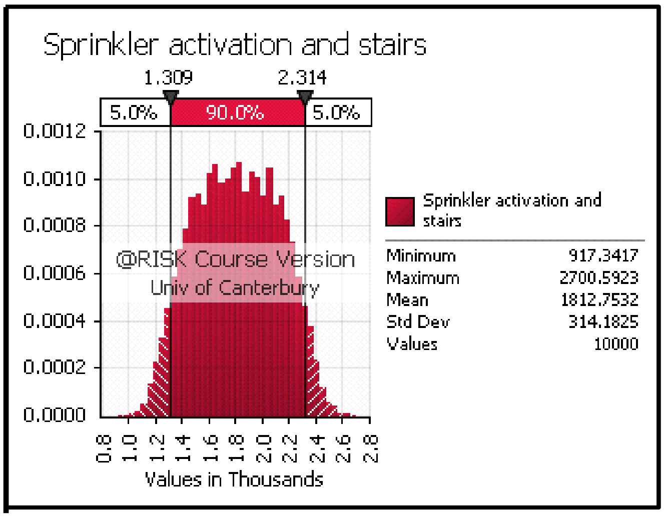
Appendix K

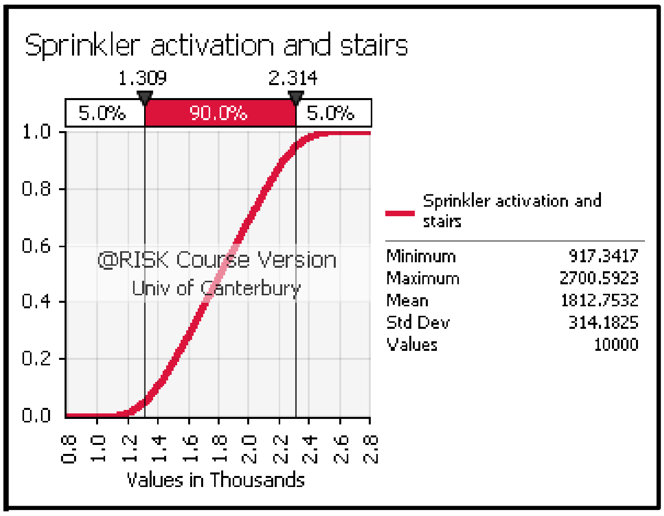
Chapter 10 FBIM Simulation results

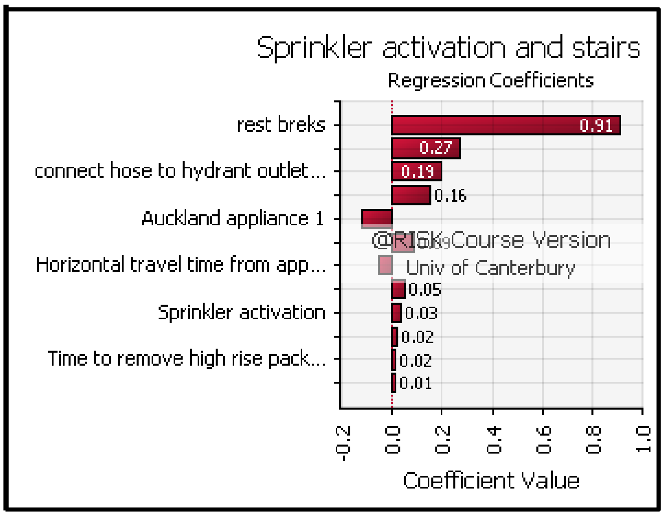
@RISK Output Report for Sprinkler activation and stairs

Performed By: NZFS User

Date: Wednesday, 28 July 2010 9:31:08 p.m.







Simulation Summary Information	
Workbook Name	FBIM High rise scenario.x
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	19
Number of Outputs	9
Sampling Type	Latin Hypercube
Simulation Start Time	7/27/10 21:26:29
Simulation Duration	00:00:29
Random # Generator	Mersenne Twister
Random Seed	1973709033

Summary Statistics for Sprinkler activation

Statistics		Percentile	
Minimum	917.3417	**5%**	1309.1035
Maximum	2700.5923	**10%**	1389.1644
Mean	1812.7532	**15%**	1457.1299
Std Dev	314.1825	**20%**	1509.5473
Variance	98710.6517	**25%**	1563.7507
Skewness	0.007032945	**30%**	1615.6161
Kurtosis	2.154512268	**35%**	1662.5696
Median	1811.1492	**40%**	1713.2751
Mode	1807.3417	**45%**	1763.5771
Left X	1309.1035	**50%**	1811.1492
Left P	5%	**55%**	1859.3794
Right X	2314.2673	**60%**	1911.1973
Right P	95%	**65%**	1959.4933
Diff X	1005.1638	**70%**	2013.0833
Diff P	90%	**75%**	2063.1793
#Errors	0	**80%**	2115.1317
Filter Min	Off	**85%**	2170.2093
Filter Max	Off	**90%**	2230.4247
#Filtered	0	**95%**	2314.2673

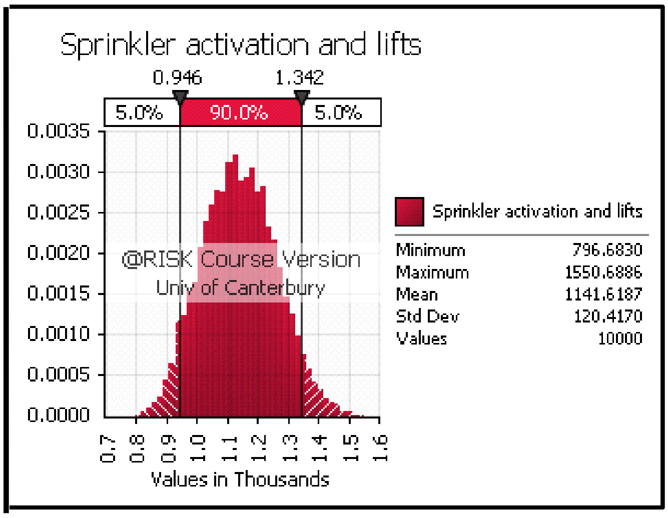
Regression and Rank Information for Sprin

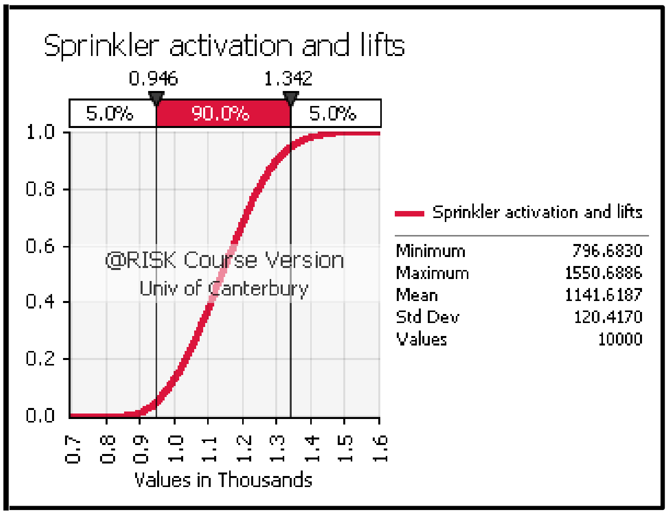
Rank	Name	Regr	Corr
1	rest breks	0.909	0.917
2	Time to depressu	0.275	0.268
3	connect hose to	0.195	0.180
4	Firefighter stair t	0.156	0.152
5	Auckland appliar	-0.117	-0.114
6	Time to dress an	0.088	0.064
7	Horizontal travel	-0.051	-0.063
8	Time to relay dis	0.047	0.016
9	Sprinkler activati	0.035	0.017
10	ascend stairs w	0.020	0.027
11	Time to remove h	0.016	0.020
12	Time to dismount	0.014	0.035

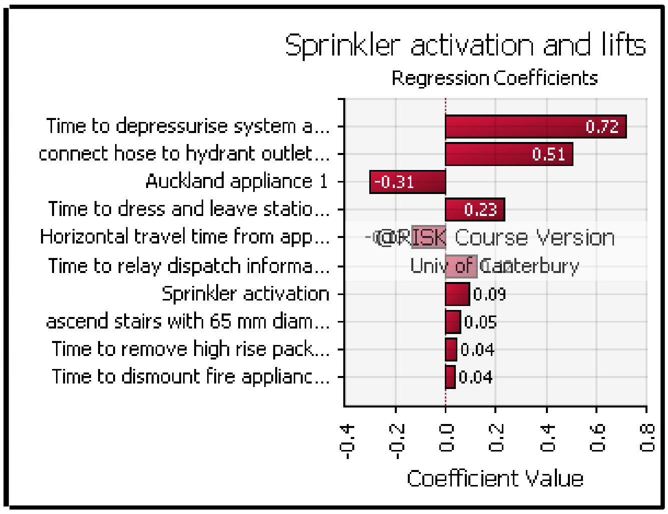
@RISK Output Report for Sprinkler activation and lifts

Performed By: NZFS User

Date: Wednesday, 28 July 2010 9:33:35 p.m.







Simulation Summary Information	
Workbook Name	FBIM High rise scenario.x
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	19
Number of Outputs	9
Sampling Type	Latin Hypercube
Simulation Start Time	7/27/10 21:26:29
Simulation Duration	00:00:29
Random # Generator	Mersenne Twister
Random Seed	1973709033

Summary Statistics for Sprinkler activation

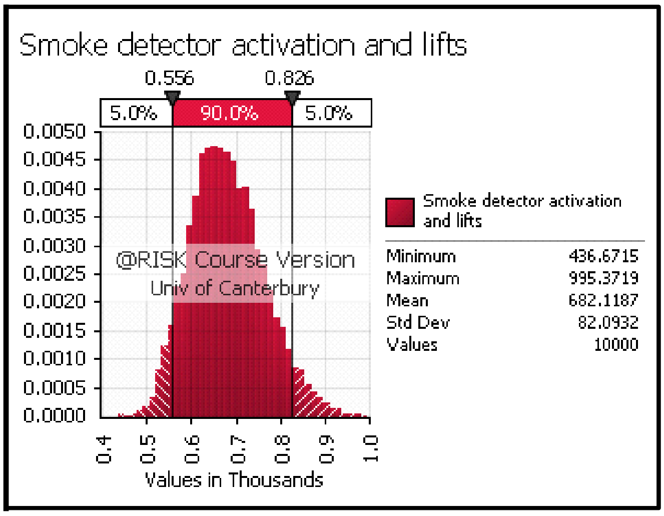
Statistics		Percentile	
Minimum	796.6830	**5%**	946.1833
Maximum	1550.6886	**10%**	983.3138
Mean	1141.6187	**15%**	1011.0583
Std Dev	120.4170	**20%**	1033.9429
Variance	14500.25255	**25%**	1053.3798
Skewness	0.116366607	**30%**	1072.3154
Kurtosis	2.623780144	**35%**	1089.9337
Median	1138.9161	**40%**	1107.6388
Mode	1178.2102	**45%**	1122.7035
Left X	946.1833	**50%**	1138.9161
Left P	5%	**55%**	1156.8496
Right X	1341.8754	**60%**	1173.6683
Right P	95%	**65%**	1190.4709
Diff X	395.6920	**70%**	1207.7543
Diff P	90%	**75%**	1225.9028
#Errors	0	**80%**	1246.5162
Filter Min	Off	**85%**	1269.9491
Filter Max	Off	**90%**	1298.2647
#Filtered	0	**95%**	1341.8754

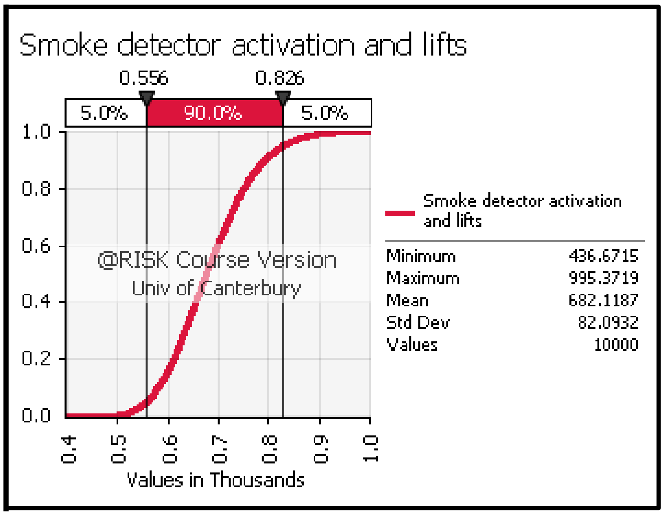
Regression and Rank Information for Sprin

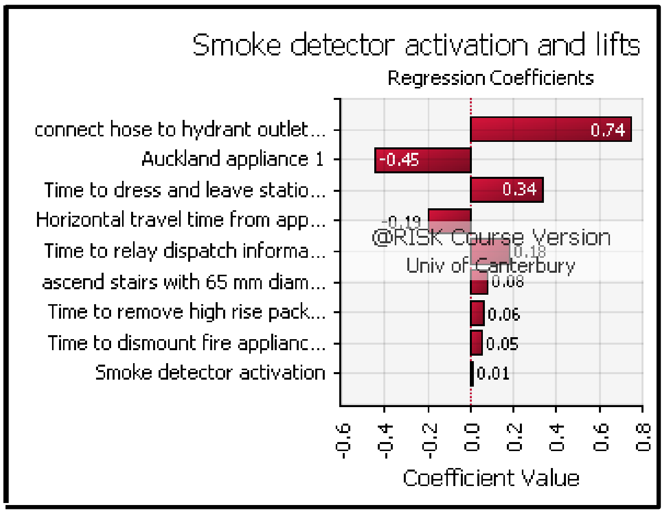
Rank	Name	Regr	Corr
1	Time to depressu	0.716	0.735
2	connect hose to	0.508	0.497
3	Auckland appliar	-0.306	-0.272
4	Time to dress an	0.230	0.209
5	Horizontal travel	-0.133	-0.139
6	Time to relay dis	0.122	0.102
7	Sprinkler activati	0.090	0.067
8	ascend stairs w	0.053	0.054
9	Time to remove h	0.042	0.035
10	Time to dismount	0.036	0.044

@RISK Output Report for Smoke detector activation and lifts

Performed By: NZFS User
Date: Wednesday, 28 July 2010 9:35:14 p.m.







Simulation Summary Information	
Workbook Name	FBIM High rise scenario.x
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	19
Number of Outputs	9
Sampling Type	Latin Hypercube
Simulation Start Time	7/27/10 21:26:29
Simulation Duration	00:00:29
Random # Generator	Mersenne Twister
Random Seed	1973709033

Summary Statistics for Smoke detector act

Statistics		Percentile	
Minimum	436.6715	**5%**	556.1802
Maximum	995.3719	**10%**	579.5643
Mean	682.1187	**15%**	597.7174
Std Dev	82.0932	**20%**	611.3545
Variance	6739.295231	**25%**	623.4207
Skewness	0.361647667	**30%**	633.8218
Kurtosis	2.950060728	**35%**	644.5302
Median	676.0330	**40%**	654.8508
Mode	662.2466	**45%**	665.2964
Left X	556.1802	**50%**	676.0330
Left P	5%	**55%**	686.8305
Right X	826.2678	**60%**	698.4005
Right P	95%	**65%**	710.3426
Diff X	270.0876	**70%**	722.6249
Diff P	90%	**75%**	734.9016
#Errors	0	**80%**	750.7699
Filter Min	Off	**85%**	768.5844
Filter Max	Off	**90%**	792.2406
#Filtered	0	**95%**	826.2678

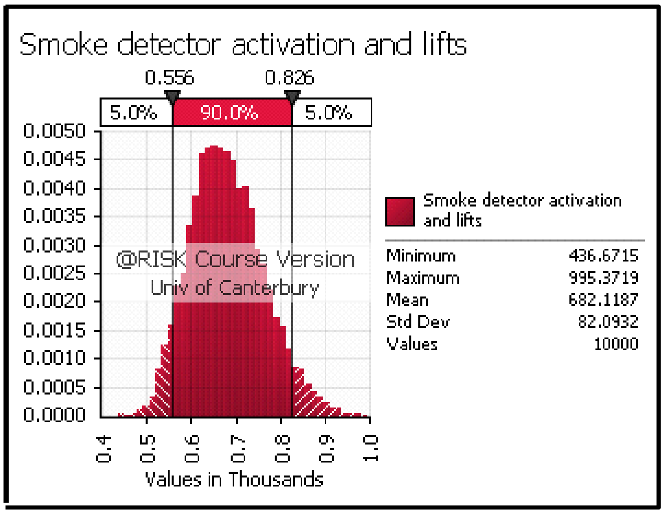
Regression and Rank Information for Smok

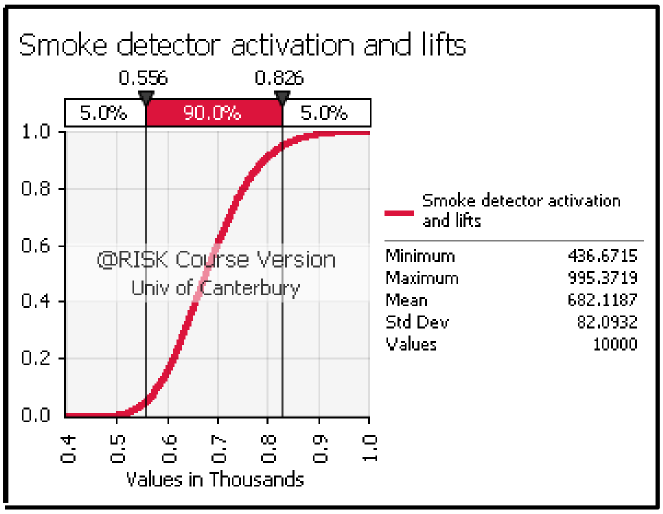
Rank	Name	Regr	Corr
1	connect hose to	0.745	0.750
2	Auckland applian	-0.449	-0.410
3	Time to dress an	0.337	0.314
4	Horizontal travel	-0.194	-0.173
5	Time to relay dis	0.180	0.151
6	ascend stairs w	0.078	0.090
7	Time to remove h	0.061	0.042
8	Time to dismount	0.053	0.074
9	Smoke detector	0.008	0.007
10	Time delay for al	0.000	0

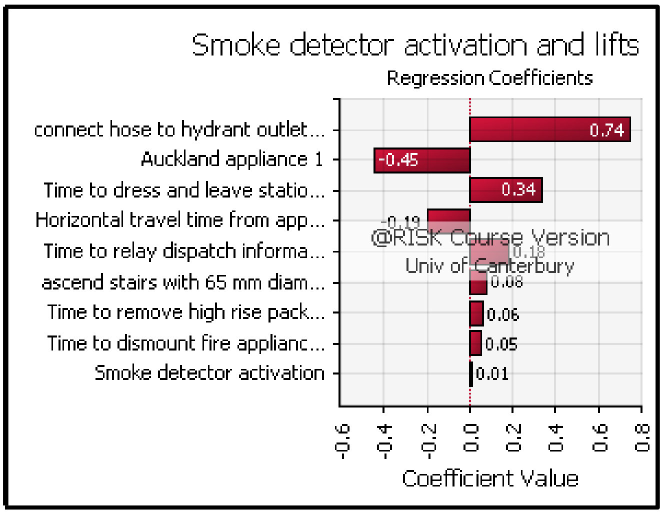
@RISK Output Report for Smoke detector activation and lifts

Performed By: NZFS User

Date: Wednesday, 28 July 2010 9:35:17 p.m.







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10	Time delay for al	0.000	0